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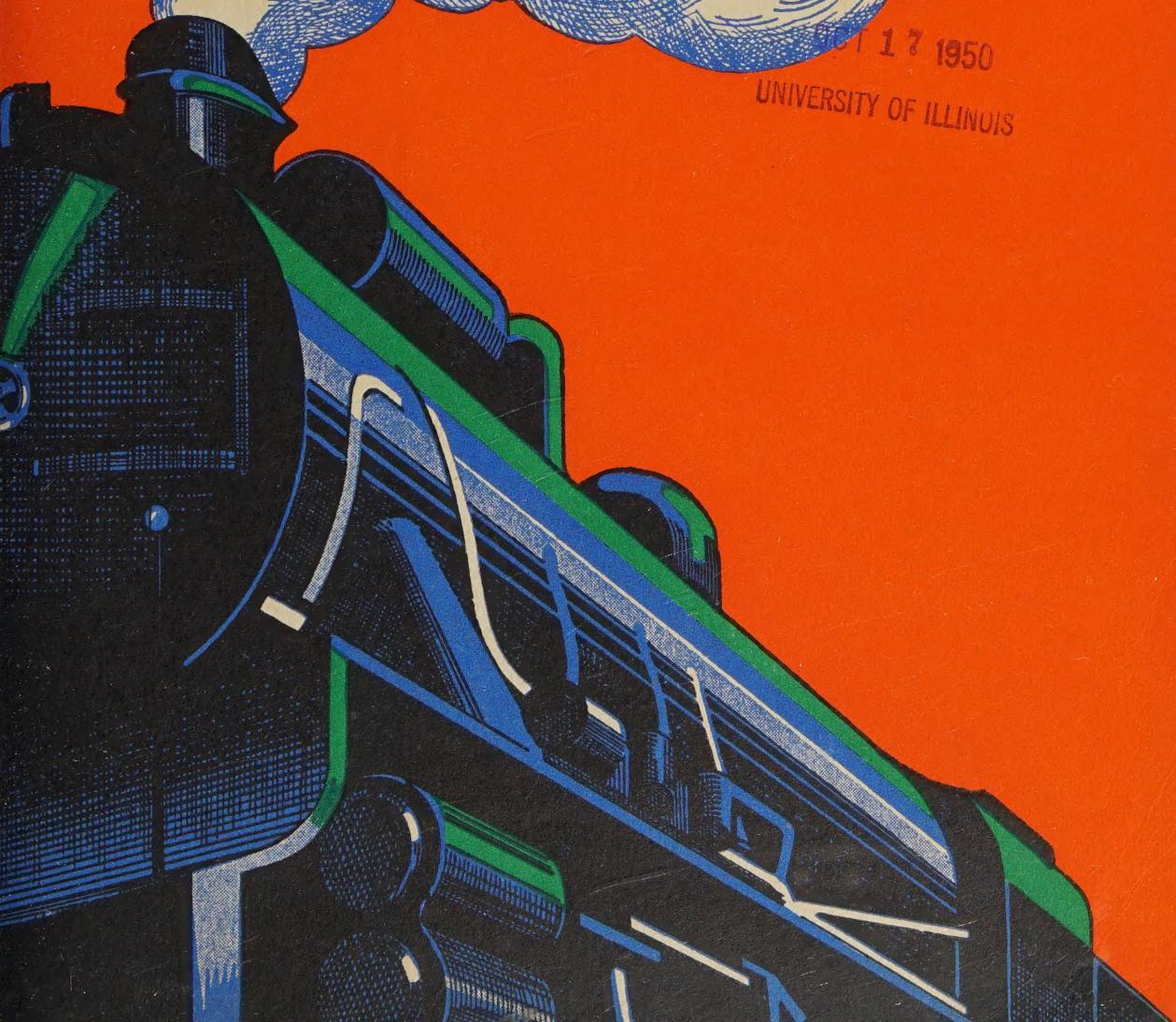
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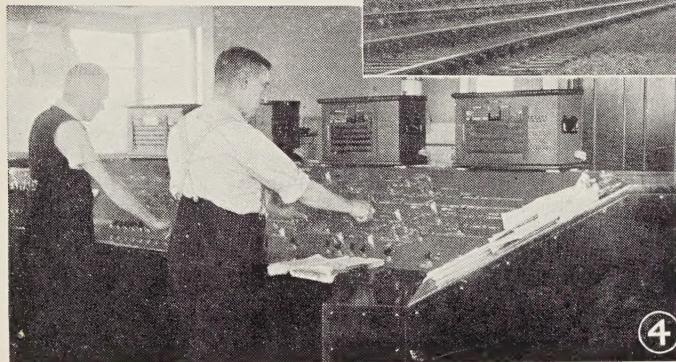
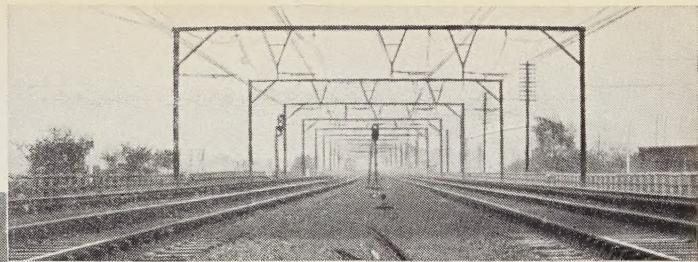
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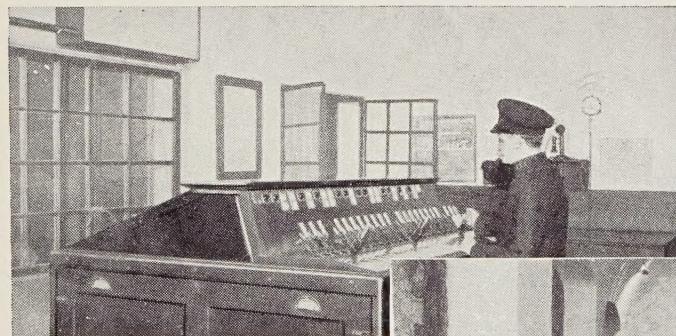


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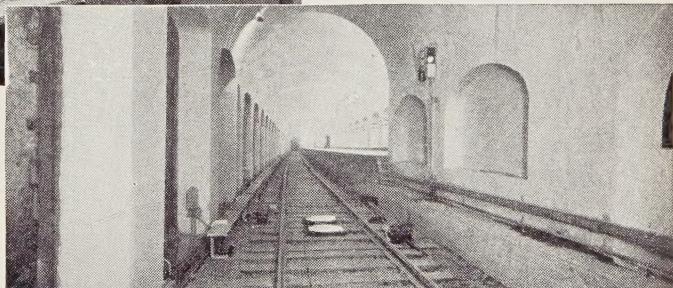


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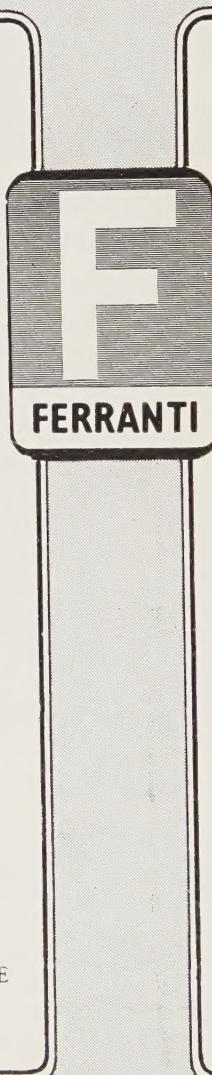
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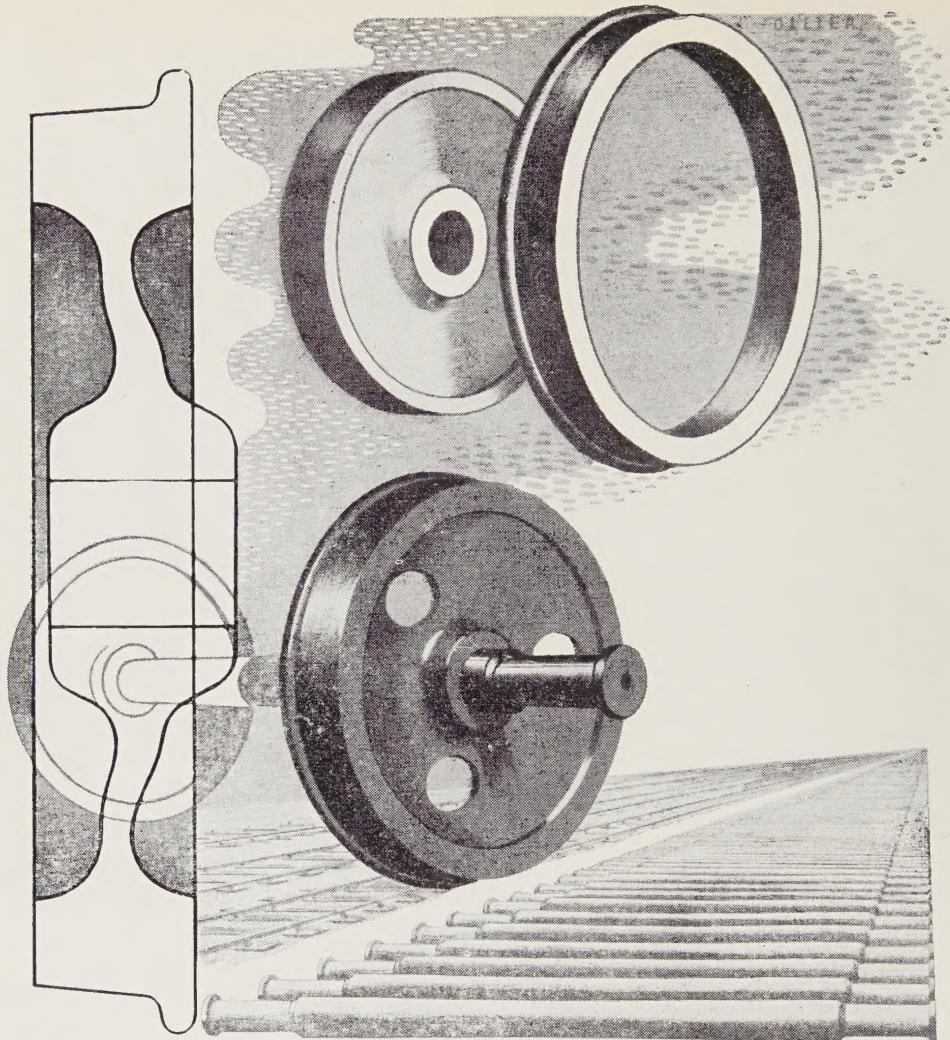
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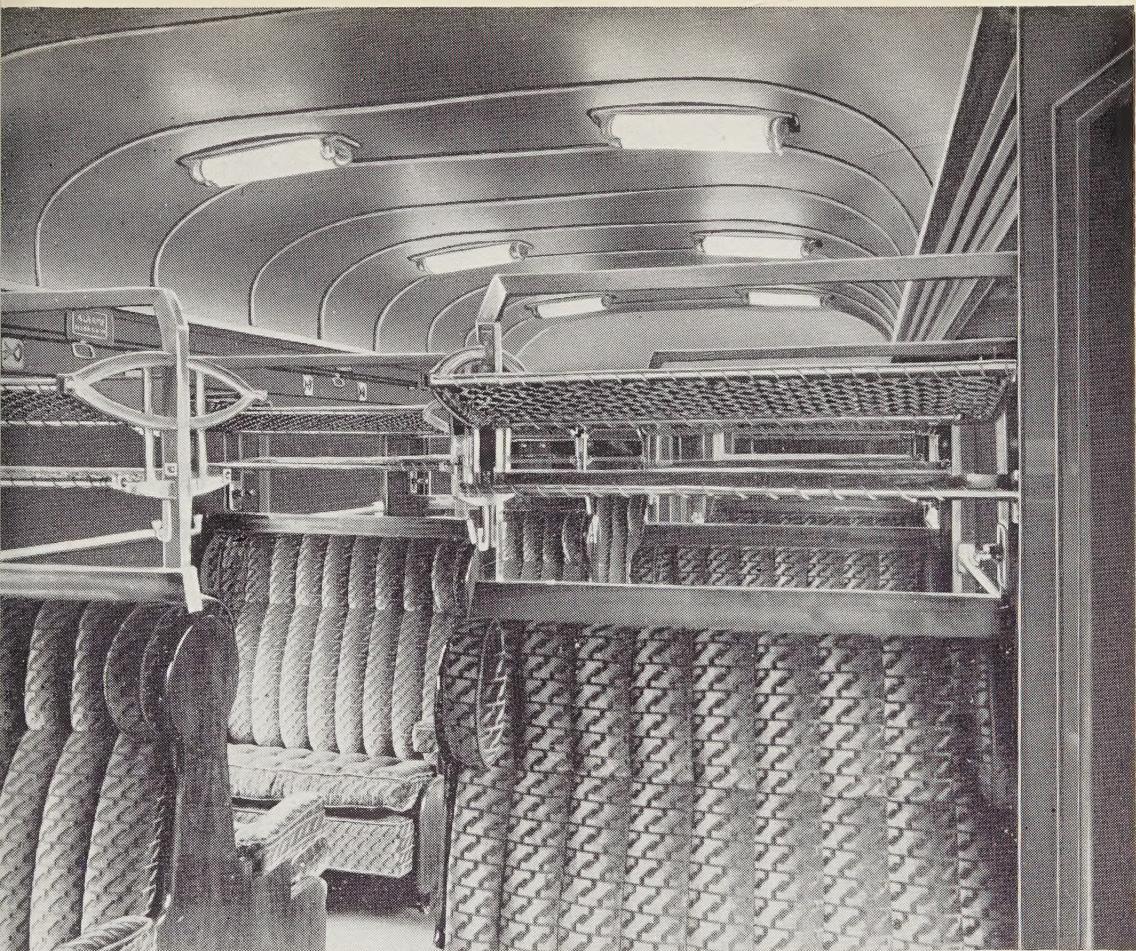


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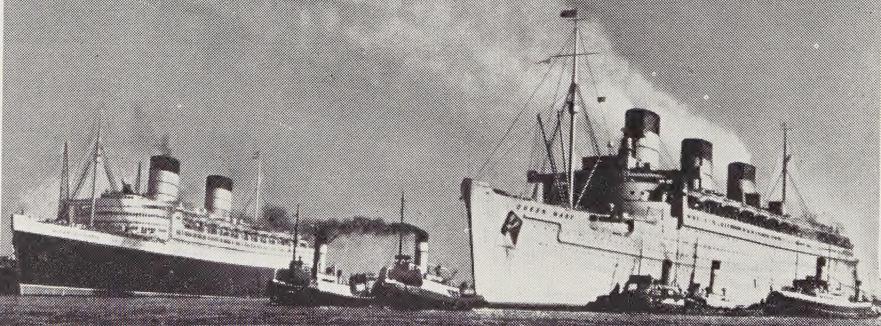
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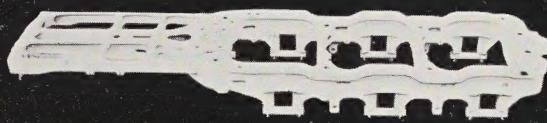
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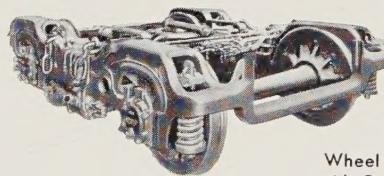
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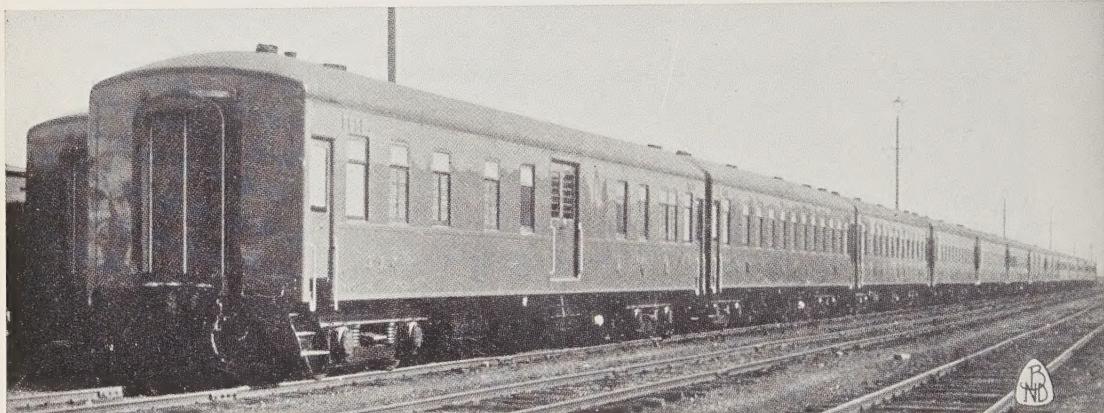
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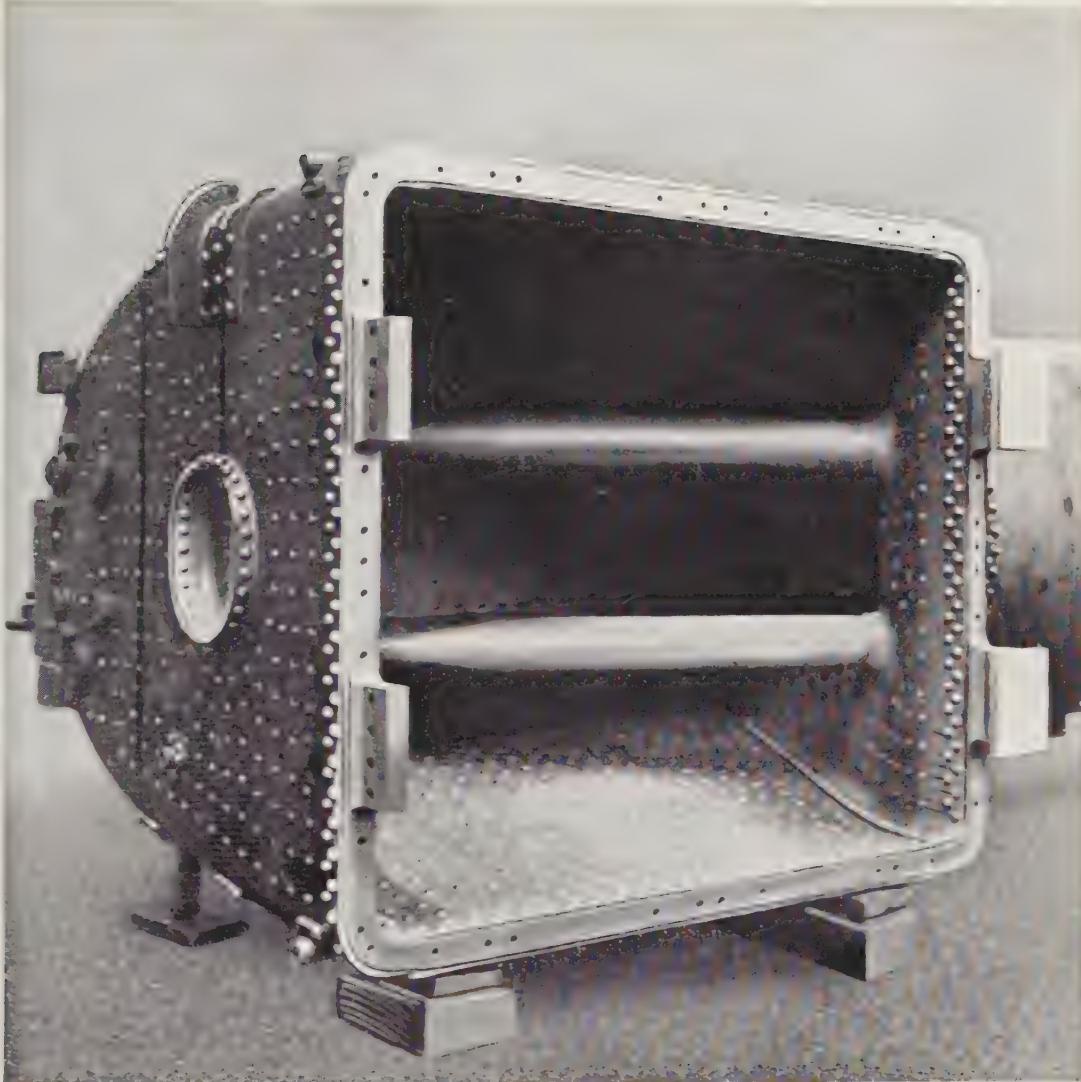


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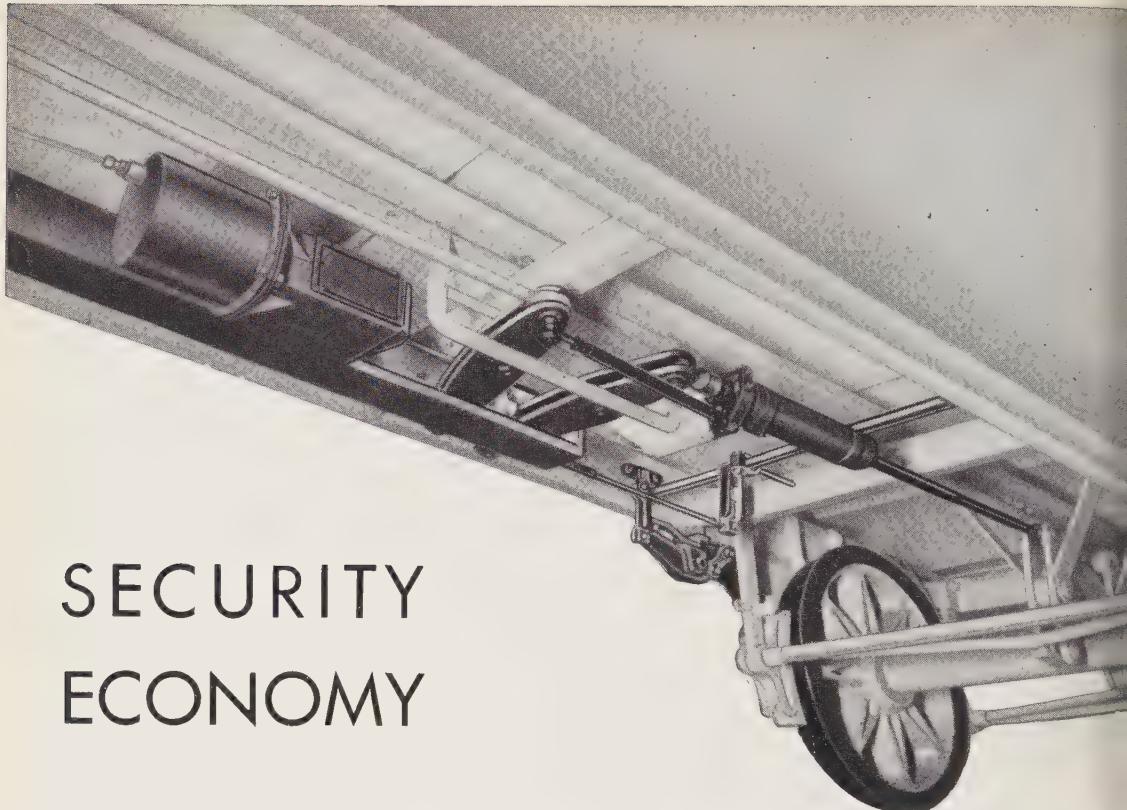
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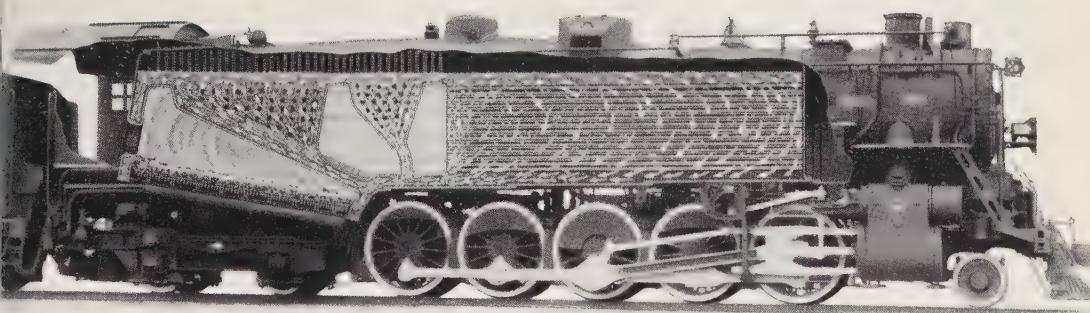
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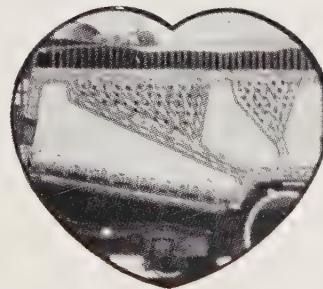
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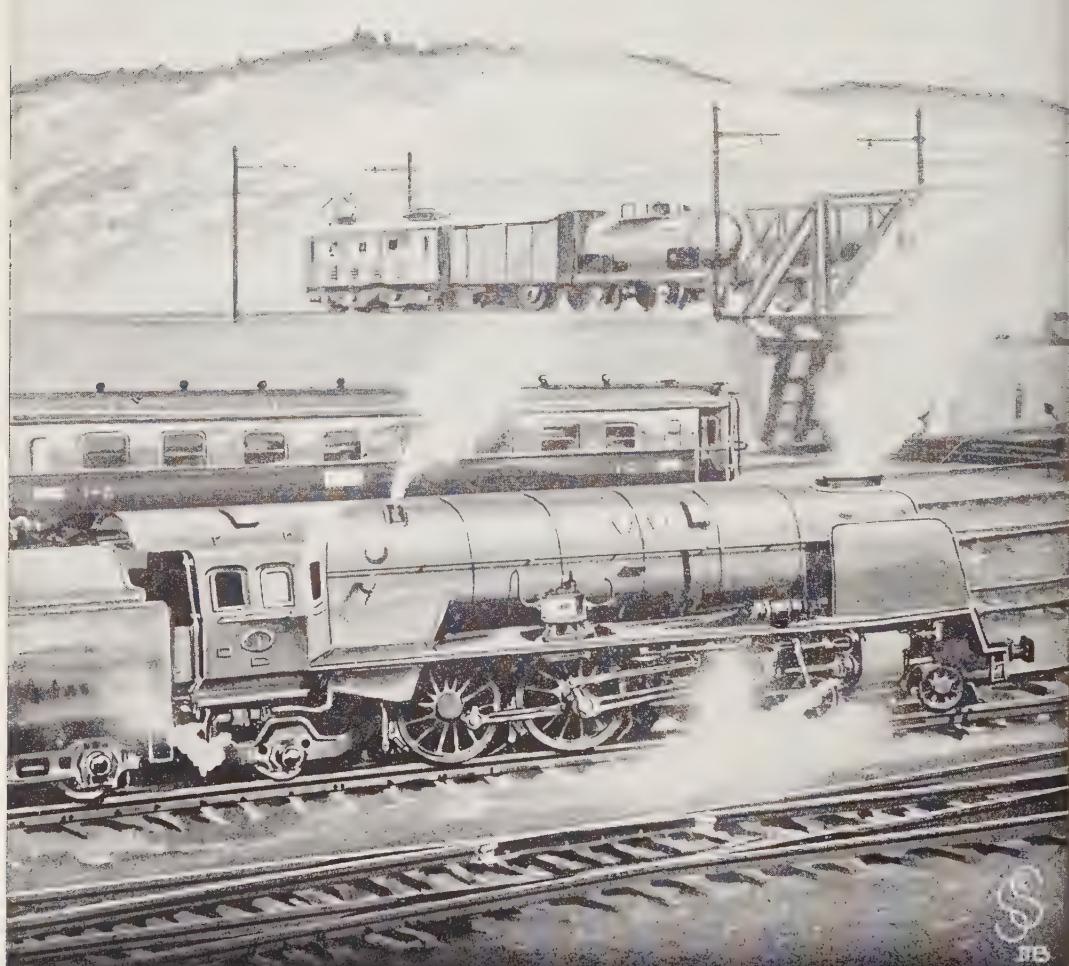
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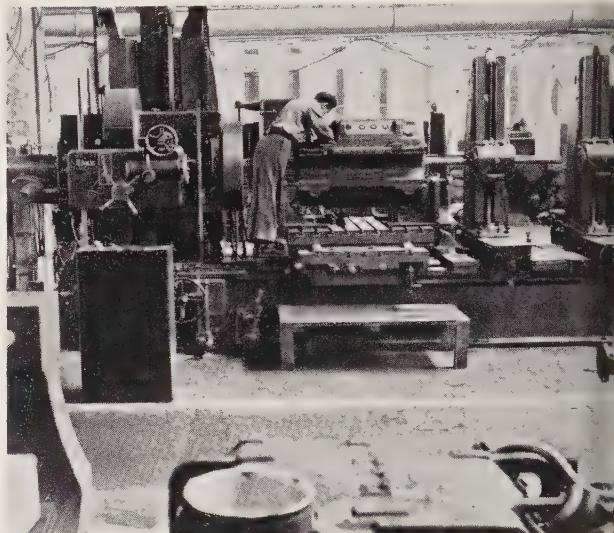
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# MONTHLY BULLETIN

OF THE

# INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

(ENGLISH EDITION)

PUBLISHING and EDITORIAL OFFICES : 19, RUE DU BEAU-SITE, BRUSSELS

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**BULLETIN**  
OF THE  
**INTERNATIONAL RAILWAY CONGRESS**  
ASSOCIATION  
(ENGLISH EDITION)

**SPECIAL ACCOUNTS**

summing up the reports on the questions for discussion at the fifteenth Session of the International Railway Congress Association (Rome, 1950).

**SECTION I. — Way and works.**

[ 624 & 691 ]

**QUESTION I.**

**Modern tendencies in the building of railway structures, especially bridges. — Results obtained in the construction of railway bridges in reinforced concrete. — Future prospects of the pre-stressed concrete,**

by M. l'Ing. Prof. G. POLSONI,  
Special Reporter.

**PREAMBLE.**

The object of the present Report is to summarise the 3 following Reports relative to Question I.:

Report (America (North and South), Burma, China, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan), by A. DEAN. (See *Bulletin* for March 1950, p. 259.)

Report (Belgium and Colony, Luxemburg, Netherlands and Colonies, Norway, Denmark, Switzerland, France and Colonies, Poland and Syria), by L. MARGUERAT. (See *Bulletin* for August 1950, p. 1657.)

Report (Italy, Spain, Portugal and Colonies, Bulgaria, Sweden, Turkey, Greece, Czechoslovakia, Yugoslavia, Finland, Rumania, Hungary and Austria), by G. POLSONI. (See *Bulletin* for September 1950, p. 1887.)

Of all the Railway Administrations consulted, 21 only have replied to the questionnaire drawn up by the Reporters.

The Reporters, commenting in the Preamble on the object of the inquiry, stated as follows :

The object of this enquiry is not to repeat purely and simply that which has already appeared in technical literature. Railway Administrations have a large number of structures; their specialists deal with a wide variety of types of construction and their experience includes the results of their own investigations and research.

It is considered that the enquiry will have greatest value if it is framed to obtain the views of engineers having such a long and close association with this type of work, and therefrom to formulate some of the modern tendencies and to make forecasts of the future.

In this regard, we hope we have succeeded, through these 158 questions, which often touch on specialised fields, in obtaining the views, experiences and conclusions of the specialists of the various Railway Administrations.

We wish to express our gratitude to all those Railway Administrations who were kind enough to supply us with all the documents and information necessary for the success of our work.

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#### PART I.

### MODERN TENDENCIES IN THE CONSTRUCTION OF WORKS OF ART, SPECIALLY BRIDGES.

#### a) Construction of railway bridges.

##### CHAPTER I.

###### *General indications concerning the design of railway bridges.*

*Live loads.* — The theoretical loadings which at present serve as bases for the design of railway bridges are an indication of the increase in live loads during recent years consequent upon the progress made towards building ever more powerful locomotives to haul heavier trains at higher average speeds; however, in almost every country, the theoretical loadings may be said to be adequate to meet needs in the immediate- and also reasonably distant future. As a general rule, all the locomotive axles on the type train have the same loading and are equidistant. Uniformly distributed loadings are allowed in the design of railway bridges.

*Dynamic effects.* — As regards the coefficient of increase for dynamic effects, we are still in the experimental stage and, in this respect, account will have to be taken of the fact that the maximum speed of trains has already reached 120-130 km/h. (75-80 m.p.h.), and that for the fastest trains a speed of 150 km/h. (93 m.p.h.) is expected. On the other hand, where the other dynamic stresses are concerned (braking, lateral effects, etc.) a certain unity of views has already been reached.

*Wind — Temperature.* — The effects of wind and temperature are considered in terms of the local conditions prevailing in the various countries.

*Shrinkage of the concrete.* — Shrinkage is generally taken as being produced by a drop in temperature of 15° to 20°. There is no experience yet to hand regarding creep (fluege).

*Choice of materials.* — The choice of the materials adopted for the construction of railway bridges is dependent on considerations of economy (taking into account not only initial cost and anticipated subsequent replacements, but also costs of upkeep to be provided for in the future), geographical location, strength of the foundation soil, availability of materials, height of structure and aesthetics.

Generally, aesthetic considerations are not lost sight of, but no recourse is had to the collaboration of an architect, save in the case of structures to be erected on particular sites.

*Repeated loadings.* — The influence of repeated loadings in metal railway bridges is taken into consideration either as a reduction in the permissible stresses or as an increase in the loads (if the frequency of the loadings is high). This influence is disregarded in all cases where reinforced concrete bridges are concerned.

*Biaxial or triaxial stresses in metal bridges.* — Polyaxial stresses are generally allowed for according to the Theory of Beltrami-Huber (constancy of the effect of deformation) or according to the Theories of Mohr, Saint-Venant and Guest.

*Non-isotropic elements in metal structures (welded seams).* — Welded elements are calculated either on basis of the average stress, or by making use of coefficients which are a function of the nature of the seam and may reduce the permissible force in the basic metal or change the stress of the welded seam to an imaginary stress.

*CHAPTER II.*  
*Metal underbridges.*

*Main Girders.* — The general tendency is towards simplifying the structures and preference is given to the simple or continuous girder with constant or sometimes varying moment of inertia.

However, span, height of structure and aesthetics may cause other systems to be chosen (particularly in respect of spans of 70 to 140 m [230 to 460 ft.]).

The frame (beam with supports) with two articulations is an interesting solution for bridge decking of light section up to a span of 40 m (131 ft.).

For spans up to 30-36 m (98-118 ft.), the plate girder is preferred as being simpler, more practical to construct and as requiring less maintenance work than the lattice types.

Height is generally 1/10th of span but may be limited to 3-3.80 m (9' 10<sup>1</sup>/<sub>8</sub>" — 12' 5<sup>5</sup>/<sub>8</sub>") if special restrictions in the road traffic are enforced.

With regard to lattice girders, preference is given to the form with parallel trellis with triangular spaces as these are isostatic, and also simpler and more economical than other types.

On double track lines, either one double track bridge or two single track bridges are built; however, in the case of skew bridges, two single track bridges are generally preferred.

Electric welding for metal railway bridges is not yet a general practice; however, those Administrations which make current use of welding report that it is satisfactory. It would appear, in the case of plate girders, that flat plates (grooved section) of the type used in Sweden are the best, as they give the girder a monolithic character and allow of controlling to be effected with X- or Y-rays.

The welded lattice girder is not so often met with in practice and generally it is preferred to weld individual elements in the workshop and assemble them on site with riveted joints. Normal type laminated girders are also used for lattice bridges.

The maximum welded thickness is generally 50 mm; however, it is expected that welding up to a thickness of 70 mm (to be standardised for thicknesses above 50 mm) will be permitted for A 37 and A 44 qualities of steel, and up to 65 mm (to be standardised for thicknesses above 30 mm) for A 48 and A 52 steels.

Qualities of steel in normal use are: A 37 to A 52, having a limit of elasticity of 24 kg/mm<sup>2</sup> (15.24 t. per sq. inch) and 20-24 % elongation.

Special steels are not in current use, as their resistance to repeated stresses is generally held to be relatively low; the use of these steels and light alloys, not as yet employed, is under consideration for special structures.

Railway bridges of the type known as « composite » (metal girders — concrete slab) have been built with either simple or continuous girders. As a general practice, the supports of continuous girders are cut down so as to suppress the tractive stresses in the concrete. The junction between the concrete slab and the main girders is made either by irons welded to the girders or by cross-stays placed very close together and completely encased in concrete.

The maximum lengths of spans where roller supports are used is from 10 to 70 m (33 to 230 ft.) and, where special devices (sliding joints) are used permitting equivalent expansion of the rails, 50 to 200 m (164 to 656 ft.).

*Bridge decks of all-metal construction.* — Generally, the track is laid on sleepers, which ensures easier maintenance, better line and level of the track and less serious consequences in the case of a derailment occurring.

The connections of railbearers to cross-girders and of cross-girders to main girders are generally riveted and preference is given to railbearers fitted into the cross-girders.

Sleepers are used to fasten the permanent way onto the metal deck of a bridge; in

the case of skew bridges, these sleepers are placed according to a fan-shaped pattern.

With regard to dynamic effects, both real and theoretical, it may be said that their study still offers an interesting field of investigation for, as yet, no satisfactory solution has been found to the question of the influence of the state of the track and of rail-joints. (It has appeared advisable to take the incremental dynamic effect due to the irregularities of the track, the rail-joints and the wheels as being equal to that which would be produced by a concentrated stress on each track of  $N^2/6$  tonnes, where  $N$  = the velocity in revolutions per second of the driving wheels of a locomotive.)

As a general practice, rail-joints are avoided; the maximum welded length of rails is 300 m (984 ft.).

Anti-derailment devices are in general use; their type varies from one Administration to the other.

*Concrete decks.* — Several Administrations make use of reinforced concrete slabs, which rest on the metal-work of the main girders; this system has the great advantage of not having any break in the ballast.

This type of deck is under consideration for high level bridges. The track runs onto the bridge without any special device apart from check-rails.

The minimum depth of ballast of normal caliber is 25-30 cm, and for ballast of a caliber up to maximum 25 mm, 8-10 cm.

The waterproof coating consists of a layer of asphalt (6-25 mm thick), or a layer of bituminised cement (30-40 mm thick), or again cement mortar (40 mm thick) or bituminised jute 5-10 mm thick.

Check-rails are used for large spans.

The generally held opinion with regard to the dynamic effects due to rail-joints is that these are less in the case of concrete decked bridges than metal decked bridges.

There are a few examples of construction where the track is carried directly on the concrete slab, through either rubber plates or rails set into the deck.

### CHAPTER III.

#### *Masonry railway bridges. — Concrete, natural or artificial stone.*

The use of these types of bridge, which always find a wide application due to the heavy overloads which they can take, and the practically negligible amount of maintenance work which they require, is generally dependent on the nature of the subsoil and the geographical configuration of the site.

The choice of the type of masonry generally depends on the availability of materials, and each Administration uses a method of calculation and a building technique adapted to the particular conditions obtaining in the country concerned. With this type of bridge, spans of a width of 100 m (328 ft.) may be reached.

Standard type-drawings are used for small spans; for spans of 15-30 m, dimensions are worked out according to the « Séjourné » method, while for large arches, recourse is had to the theory of elasticity or the resistance coefficients of the materials.

In general, when a masonry arch has been designed as articulated, foundations rendering this indispensable, the articulations are effectively realised.

It is of advantage to reduce the thickness of round arches above a span of 15-20 m, and of flattened arches at spans above these figures.

As a general rule, very thick or large arches are constructed with several separately laid rings; these rings are bonded together by redans or metallic anchoring bars.

With regard to the modulus of elasticity, calculations are generally based on the experimental value of 100-120 t/cm<sup>2</sup>. Shrinkage, which is usually disregarded in stone masonry arches, is very pronounced in the case of concrete arches and concreting by voussoirs with binding is used in their construction. The extrusion (flueage) is only taken into consideration for large arches; its action is compensated by regulating the line of pressure by means of jacks or by means of provisional articulations.

The dressings seen of the works in concrete are everywhere treated with great simplicity. The facing with block masonry is usually limited, and the bind between concrete and stone is always good. The masonry of the artificial voussoirs is generally used for the finishing off of bridges.

The gauging of cement is from 250 to 350 kg/m<sup>3</sup> of concrete used; the thickness of the aggregates runs normally to 70 mm.

Vibration by means of pervibrators is universally employed.

The filling material between the tympanum walls is either thin concrete or assorted dry stone.

The watertight cappings are either a layer of asphalt, cement mortar or bituminised jute. The watertight cappings, with a minimum slope of 2-2.5 %, are positioned either directly on the extrados of the arches or else on a thin concrete filling between the tympanum walls.

Water drainage pipes, with a minimum diameter of 8-10 cm, are taken through the arches at a maximum distance of 30 m.

The use of expanding cement has so far been limited to the repairing of partly damaged arches.

Where bridges are built in two stages, the two halves are separated by a longitudinal joint.

As a general rule, the dynamic effects are not taken into consideration when the permanent load is much greater than the live loads anticipated.

On arched bridges, check-rails are sometimes installed to lessen the possibility of derailments.

#### CHAPTER IV.

##### *Railway bridges with beams encased in concrete.*

The system of construction using girders encased in concrete is considered to offer considerable advantage as far as simplicity, rapidity in erection and reduced height of structure are concerned.

This type of bridge is economical up to a span of 20 m (65 ft.), but bridges with spans up to 28 m (92 ft.) have been built.

It is a general practice to use standard type-drawings.

Transverse mountings are built in a purely empirical manner. The adherence and tractive stresses in the concrete should be controlled.

In the case of skew bridges, the girders are placed parallel to the skew span and calculated accordingly.

The girders are either visible or completely encased in concrete.

In the case of double track lines, one single slab is preferred.

Prefabricated elements may also be used, and these enable rapid replacement of existing bridges to be effected.

The track is ballasted, but owing to considerations of height, the track is sometimes laid directly on the girders.

The dynamic effects are calculated in the same manner as for reinforced concrete bridges.

With this type of bridge, maintenance costs are much reduced.

#### CHAPTER V.

##### *Road bridges and over-bridges.*

Concrete or reinforced concrete over-bridges are preferred for reasons of economy and in view of the lesser height of construction.

For over-bridges located in stations, preference goes to long span simple or continuous girders with rigid frames forming a single unit with thin reinforced concrete piers.

Roller supports are used for spans exceeding 20 m. In the case of reinforced concrete slabs, the supports used are steel plates.

The coefficient of increase for dynamic effects is taken into account in the formulae.

Pre-stressed concrete can be used with advantage in the construction of over-bridges.

#### CHAPTER IV.

##### *Piers and abutments.*

With regard to piers, preferences goes to

either massive piers in natural stone or concrete, or to relatively thin piers in reinforced concrete.

The supporting banks consist of either granite or reinforced concrete blocks.

The abutments are built of natural stone or reinforced concrete with solid return walls as this type of construction is more economical and withstand the thrust of the earth better.

In calculations, the total horizontal stresses acting on the deck are allowed as being transmitted to the foundations.

Frequently, the fixed supports are sited on piers.

### b) Other structures.

#### CHAPTER VII.

##### *Retaining walls.*

Semi-empirical formulae are in current use for determining the thrust of the earth, but in the case of large structures, where the foundation soil may have to be reinforced by artificial means, recourse is also had to earth loading tests or to geotechnical studies.

#### CHAPTER VIII.

##### *Tunnels.*

Generally speaking, the concrete facings are not protected against corrosion by smoke. Protection may be obtained by applying two coats of a solution of 80 % of fluosilicate of lead and 20 % of water, or a solution of asphalt put on cold or again, a layer of liquified cement.

To avoid losses of current on electrified lines due to damp, the masonry is protected by waterproof cappings and, in the case of cracks occurring, by injections of cement or cement mortar, or by appropriate drainage.

#### CHAPTER IX.

##### *Platform roofs.*

The materials preferred for the construction of platform roofs are reinforced concrete, steel and wood.

Occasionally, independent platform roofs

are fitted with glazed sky-lights at their extremities.

Dissymetrical loads allowed for in the calculations are generally snow and wind loading; the values attributed to such loads vary from one Administration to another.

### c) Testing of railway bridges.

#### CHAPTER X.

##### *Testing of bridges.*

Tests are of two kinds, i.e.: static and dynamic, and their purpose is to ascertain whether the actual stresses and deformations are the same as those allowed for in calculation; when these tests are carried out when the bridge is being used, they also serve to check the comportement of the bridges under actual working conditions.

Usually load tests are carried out by the Bridges and Highways Department or Service.

Recording apparatus is used to measure particularly the dynamic effects of live loads and to control the effects of slow acting stresses (fluege = extrusion).

Much importance is attached to the usefulness of sounding bridges in order to ascertain the frequency of vibrations, to keep a check on them throughout their whole life and to be able to take the results of such test into account when designing similar structures.

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### PART II.

#### Results obtained in the construction of reinforced concrete bridges.

The first reinforced concrete railway bridges were built about 1900 and one of these structures is still in service; however, reinforced concrete may be taken as having left the experimental stage in 1920.

Today, the use of reinforced concrete in the building of bridges is assuming wide proportions and it may be asserted, on basis of the results obtained during tests, that reinforced concrete is a suitable

material for the construction of railway bridges.

The one-piece concrete slab is used up to spans of 12-15 m, « T »-section or hollow beams are in use for spans up to 25 m and « T »-section variable inertia continuous beams up to spans of 44 m.

Other systems of construction comprise the more or less flattened arch, the encased or articulated frame or the parapet girder.

In general, the steels used are: A 37; Aq 42 Aq 44. The use of high resistance steels is limited by the cracking of the concrete. Welded joints are, in general, permitted. The essential requirements to ensure a good metallic reinforcement assembly are: qualified work gangs and strict supervision during the work, adequate distribution of the metal reinforcement (particularly in those zones which are under tension), rigid and well held reinforcement assembly.

The minimum thickness of the concrete encasement varies according to the type of structure, the diameter of the reinforcement irons and the positioning of the reinforcement assembly: minimum diameter is 15-20 mm.

The proportion of cement in the concrete is 300-400 kg per  $m^3$  of aggregates of correct granulometric calibre. The essential conditions for producing a good concrete are: good quality of the cement, the inert substances and the water, correct granulometric calibration of the aggregates and correct proportion of water, protective measures to guard against wide variations of temperature and freezing during building operations, careful manufacture, use of proportions of ingredients as fixed by laboratory research and correct vibration of the concrete.

Cracks, probably due to shrinkage, have been noted in reinforced concrete; these can be prevented or limited by building a secondary or auxiliary armature or by making test calculations based on Saliger's Theory on fissuration.

The cements used are: Portland cement, cement mixed with « puzzolane » and high

resistance cement. As a general rule, special cements have not been used, except in some special cases, when liquified cement and ultra high resistance cement mixed with a special ingredient to make it set rapidly are employed.

Ingredients to increase the handling qualities and compactness of concrete are not in current use. Good compactness and good durability are considered as being sufficient to ensure protection of reinforced concrete against the effects of the weather.

As a general rule, the calculations for the design of reinforced concrete railway bridges are based on the generally accepted theory for reinforced concrete design, compression stresses being taken into account for the concrete and tractive stresses for the steel armature.

The maximum permissible stresses in the concrete are calculated as a certain percentage of the resistance under compression of test pieces over a period of 28 days (in general the limit percentage is 1/3-1/2.5 of the resistance at breaking point). Where the resistance at breaking point is greater than 225-250 kg/cm<sup>2</sup>, the permissible stress may reach up to 110-120 kg/cm<sup>2</sup>.

The maximum permissible stresses in the reinforcement are determined on basis of the limit of elasticity of the steel — the limit for A 37 steel is 1200 kg/cm<sup>2</sup>, for A 44 steel 1400 kg/cm<sup>2</sup> and for semi-hard steel 1800 kg/cm<sup>2</sup>.

The formulae giving the increment for dynamic effects show wider variations than in the case of metal railway bridges; however, they are based on experience and are satisfactory.

The transversal distribution of live loads over the width of the slab is 3-5 m.

Calculations for skew bridges are generally based on the skew span and the main reinforcements are positioned according to the length of span accepted in the calculations. The maximum skew angle allowed is 70°.

The supports of full slabs consists of rails or flat bars. In the case of beams, these supports are of the sliding type for

spans of 8 to 20 m and of the roller or rocker type where the spans are greater than 15-20 m.

The coefficient of friction is 30 % of the vertical load for sliding bearings and 5 % for roller type supports.

As a general practice, articulations are avoided; however, reinforced concrete articulations have shown themselves to be satisfactory.

Railway bridges built with pre-fabricated components are very rare.

Generally speaking, regulations concerning waterproof protective cappings and the depth of ballast are the same as in the case of bridges with concreted decks or with encased joists.

Experiments are at present being carried out with track laid directly on the concrete slab.

In general, repairs to the concrete work have not caused any great trouble and no serious damage has been noted in the case of reinforced concrete railway bridges.

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### PART III.

#### **Pre-stressed concrete and its future possibilities.**

Pre-stressed concrete has not yet found a wide field of use in railway bridge construction technique; however, in its present state, it is already well adapted to the construction of reservoirs and to the manufacture in series of various components such as: posts, pipes, parts of framework or platform roofs.

As far as bridges are concerned, there are a few examples of railway bridges for meter gauge track with spans up to 18 m, and for normal gauge track with spans up to 12 m. On the other hand, several road bridges have been built and, in the case of over-bridges, a span of 35.50 m has already been reached.

Before this new technique can develop widely, it will be necessary to have a thorough knowledge of what the life of pre-stressed concrete will be under working

conditions, the relaxation phenomena, extrusion (fluege), the steels used, the effects of shocks, and to improve the technique of building and in particular that of the reinforcement assemblies.

Future prospects in the use of pre-stressed concrete must be considered in terms of complete structures pre-stressed in all their detailed parts; however, a reservation must be made in the case of partial pre-stressing in order to increase the safety of a whole structural unit.

There is no firm requirement as to the adoption of either the simple adhesion or the terminal system of anchorage however, the latter system may be preferred in the case of large spans or work on site.

The diameter of wires is limited and is, in general, from 2 to 5 mm.

The high resistance steel used has a breaking point of from 90 to 180 kg/mm<sup>2</sup> and the conventional limit of elasticity of from 80 to 140 kg/mm<sup>2</sup>.

The concrete must be made with the utmost care; the proportions of ingredients and the granulometric calibration of the aggregates being minutely controlled.

The working rate of pre-stressed concrete is 100 to 120 kg/cm<sup>2</sup> while a minimum breaking point of 250 kg/cm<sup>2</sup> may be laid down. The cement used is either normal Portland or rapid hardening cement.

Pre-stressed elements are waterproof and, as a general practice, no waterproofing arrangements are provided except for the joints where pre-stressed beam units are laid side by side.

With regard to shrinkage and creep, design is based on a 15 to 20 % loss of pre-stressing load in the wires, corresponding to a variation of temperature of 60° (shrinkage : 0.25 mm/m; creep : 0.50 mm/m).

While there does not as yet exist any long term experience of the behaviour of pre-stressed concrete bridges which have been subjected to live loads, it is considered that the dynamic effects are no higher than in the case of reinforced concrete bridges.

In view of the variations in the stresses

in the steel, under the influence of live loads, which are small compared with the permanent tension, fatigue effects are not considered as dangerous.

Generally speaking, the cost of a structure built of pre-stressed concrete is almost equal to the cost of a steel or reinforced concrete structure, but it is reasonable to expect that the costs of maintenance will be lower.

## SUMMARIES.

### 1. General. Present design requirements - live load - dynamic load, provision for fatigue.

Other than on American Railways, the live loadings now adopted are reasonably comparable and they are considered to cover future requirements.

Formulae laying down the dynamic loading, related solely to the span of a bridge do not adequately cover all dynamic components. The effect of irregularities in the track, including the effect of rail joints, should be provided for.

Special provision for fatigue effect is only made when actual reversal of total stress will occur.

Laboratory experimental work should be pursued to determine the long term effect of subjecting bridge construction materials to fluctuation of a range exceeding those hitherto normally allowed.

### 2. Metal bridges.

Decks entirely of metal construction are generally adopted when construction depth is limited. In such cases the track is generally carried on sleepers or cross ties; rail-bearers are usually fitted into the cross girders to give a shallow construction, with provision for continuity. The use of welding is still infrequent, but is being developed.

The use of reinforced concrete decks on metal bridges has been adopted widely in recent years, in conjunction with ballasted tracks, with the accompanying advantages.

Metal bridges are used for the bigger

spans, for cases of limited construction depth and where provision must be made for settlement of foundations.

Plate girder construction is economical up to spans of 100-125 ft. For longer spans lattice girders of the simplest type are used.

Mild steel of about 28-32 tons/sq. inch ultimate is used widely. The use of special steel is only recommended in special cases. The use of light weight alloys has hitherto been limited to less important members.

Welding has been adopted for the construction of medium span plate girder bridges, with apparent success up to the present. Only one case has been reported of the construction of a completely welded lattice girder bridge.

Combined steel and concrete construction, designed deliberately for composite action is a useful form which can be adopted with advantage for simple spans up to about 100-125 ft. Application to continuous girder construction involves pre-stressing the concrete deck at the intermediate piers.

There is as yet a lack of full knowledge as to the long term behaviour of this composite form of construction.

### 3. Arch bridges, built of concrete and stone.

Such bridges are generally economical, particularly in maintenance and are preferred whenever local conditions are suitable. Concrete is widely used; construction in natural stone gives improved appearance, but is generally more costly; stone faced concrete is a suitable compromise provided steps are taken to obtain a reliable bond.

Weak concrete is generally used for the backing between spandril walls.

Pin type joints are not necessary unless the long term stability of abutments is in doubt.

There exists inadequate reliable information on the precise dynamic loading of masonry arches carrying rail traffic, but it is likely to be less than for metal bridges.

*4. Underbridges comprising girders encased in concrete.*

This is a useful form of construction when construction depth is shallow and when line occupation facilities are limited. It involves a somewhat extravagant use of steel.

*5. Road bridges and over-bridges.*

For the ordinary double track bridge, wide use is made of three span reinforced concrete bridges, and in some countries of pre-stressed concrete.

It is general practice to provide as few piers as is reasonably possible in the construction of over-bridges spanning station and yard layouts.

*6. Piers and abutments.*

Mass concrete is most widely adopted for piers and abutments. Hollow construction is only considered for special cases and where the intensity of foundation loading must be kept unusually low. Reinforced concrete, or steel framed piers are adopted to reduce obstruction to visibility and where loading gauge clearance requirements restrict the possible thickness.

*7. Platform roofs.*

Steel or reinforced concrete is adopted for the framing, an umbrella type of construction being general for island platforms.

Glazing is only provided in most countries to meet particular local natural lighting requirements.

Other than where extreme climatic conditions prevail, it is usual for design purposes to provide for either snow load, or wind load, whichever is the greater, but not for both to be active simultaneously.

*8. Testing of structures.*

Site testing of structures covers the following fields:

- 1) to confirm the behaviour and capacity of a new work;
- 2) to determine the safe load capacity of old bridges;

3) to investigate special general problems such as shrinkage, creep, dynamic effects of live loads.

*9. Reinforced concrete under-bridges.*

Reports indicate that simple reinforced concrete slabs are used up to spans ranging from 18 to 48 ft.

Lighter forms of construction, using T-beams, or hollow beams, have enabled longer reinforced concrete spans to be built, particularly in continuous construction and with varying depth and section.

For long span bridges, arch construction permits the effective use of reinforced concrete.

Not only should high mechanical strength be sought, but this concrete should be of high density and proportioned to give minimum shrinkage.

Reinforcement should be provided judiciously in all parts of a bridge liable to be affected by the loading, even if such effects are of a secondary nature and have not been evaluated in the design analysis.

*10. Pre-stressed concrete.*

Pre-stressed concrete construction has already been used on several railway systems, but as yet, in only a few cases for underbridges, of spans not greater than about 36 ft. carrying usual main line loading, and 60 ft. carrying meter gauge loading.

At present, pre-stressed concrete lends itself to mass production of similar units; it also enables shallower construction to be adopted than when using ordinary reinforced concrete. It is hoped that its use will also be accompanied by reduced maintenance.

Its field of application will be extended when higher working stresses in the steel and concrete can be adopted with confidence.

There is need for more information on certain technical details relating to the practice and application of pre-stressing of concrete.

## QUESTION II.

**Rail-joints : improvements in fishplated joints. — Use of long welded rails : optimum length in relation to the safety and good condition of the permanent way. — Expansion gaps. — Determination of standard allowances,**

by O. LEDUC,

Special Reporter.

Question II was the subject of three reports :

Report (Belgium and Colony, France and Colonies, Luxemburg, Netherlands and Colonies, Norway, Poland, Switzerland, Syria), by O. LEDUC. (See *Bulletin* for February 1950, p. 127.)

Report (Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Jugoslavia, Portugal and Colonies, Rumania, Spain, Sweden and Turkey), by B. RENDA. (See *Bulletin* for March 1950, p. 167.)

Report (America (North and South), Burma, China, Egypt, Great Britain and Northern Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan), by P. CROOM-JOHNSON. (See *Bulletin* for March 1950, p. 207.)

The object of the present report is to sum up the main ideas of these three reports and try to put forward the summaries that can be derived therefrom.

## FIRST PART.

**Rail joints. — Progress made in the construction of the fishplates.**

It is striking to note that the arrangements adopted by all the railways are relatively simple. They nearly always consist of two fishplates, the section of one or the other, or sometimes of both of them, being increased to some extent by the various forms of flanges used, which also serve to prevent the head of the bolt from

turning. The ends of the rails are always cut straight. No report has been made of slanting cut in any case.

The examination only concerned permanent way of the most up to date type, with Vignole rails, the bullheaded rail having now been abandonned by nearly every railway.

The most usual weights are 45 to 50 kg (30.23 to 33.59 lbs. per ft.) per metre of rail, though they are somewhat higher on a few lines, and reach a maximum of 76.9 kg (51.67 lbs. per ft.) on the Pennsylvania Railroad.

The rails are generally laid on wood sleepers.

Metal sleepers are used by the Australian Railways, the South African Railways, the Indian Government Railways, Nizam's State Railways and Ceylon Government Railways; the Indian Government Railways also report the use of cast iron sleepers.

In most cases the joint is overhanging, to a greater or lesser degree. The only Railways to report the use of joints resting on a single sleeper were the Swedish Railways and Pennsylvania Railroad, but in the latter case the two adjacent sleepers are brought fairly close to the joint sleeper (254 mm = 10 in.) so that actually the joint is supported by three sleepers.

The method using a double sleeper is used by several railways :

— either two wooden sleepers joined together by bolts (Swiss, Netherlands and

Italian State Railways, under trial on the South African Railways);

— or metal sleepers welded together (Swiss, Belgian and South African Railways).

In these last two cases a double sole plate is often used and forms a continuous support for the rail. A bridging device is mentioned by the South African Railways who state that it did not lead to any improvement justifying the extra cost.

The Portuguese Railways also use a bridging device similar to that used on a large scale by the French Nord and Est Railways but given up by the S. N. C. F.

When the joint is overhanging, the distance between the axis of the sleepers varies.

On most of the railways of Western Europe, it is about 250 to 300 mm (9.8 to 11.8 in.). The only exception is the Portuguese Railways where it is 490 mm (19 in.).

It is 450 to 500 mm (17.7 to 19.6 in.) on the Algerian, South African, Nizam State and Victorian Railways.

The British Railways report distances of 635 mm (24.9 in.) and the London Transport Executive of 610 and 660 mm (24 and 25.9 in.).

Parallel joints are the most usual. Some railways report that they have obtained good results with staggered joints used as an experiment (Italian State Railways, Algerian, and South African Railways). Others have adopted this arrangement systematically for lines on curves (Netherlands and Indian Railways) or use it fairly generally (Pennsylvania Railroad). It is not a new method. It was used a long time ago by certain railways who ended by giving it up as they found it had more drawbacks than advantages. We have had personal experience of some such sections of line on the French Nord Railway. The results were not bad on curves of small radius, about 200 to 300 m (656 to 984 ft.), because the maintenance of the correct alignment was facilitated. In other cases staggered joints set up rather an unpleasant

rocking movement in the stock unless the level is very accurately maintained. It is true that in the case I am speaking about the rails were short ones, 8, 10 or 12 m (26, 33 or 39 ft.) long at the most. The same drawback would be much less serious in the case of recent rails which are more than 18 m (59 ft.) long. We think it would be interesting for the Railways who up to the present have only used parallel joints to follow the results of the new trials being made in this connection.

The joint is generally fixed by 4 bolts. Some railways however use fishplates with 6 holes: S. N. C. B. (CESAR fishplates), Swedish Railway Union, Pennsylvania Railroad, and Victoria Railways).

The fishplates are often 55 to 60 cm (21.7 to 23.6 in.) long. In the 4 hole types, the length is sometimes greater, and may be as much as 72 to 76 cm (28 to 29.9 in.).

The 6 hole fishplates are definitely longer, up to 91.5 cm (36 in.) on the Pennsylvania Railroad and Swedish Railway Union.

We only received a few details about the profile of the fishplates used, as follows:

— Algerian Railways: A. R. A. B. fishplates, with interior ribbing;

— Swedish Private Railway Union: angle fishplates with large horizontal wings pierced by the outer coachscrews to anchor the rail;

— London Transport Executive: the fishplates used with bull-headed rails are known as «tailed», and have a lower flange which is extended the whole length of the lower side of the head;

— The South African Railways: also used tailed fishplates with a flange extended further under the foot of the rail.

The reporters gave details of the sections, moduli of resistance and moments of inertia of the different types of fishplates reported. If a comparison is made between the different data for the same type of rail, the following points may be noted:

The sections for the pairs of fishplates, apart from the bolt holes, are of the same proportions as the corresponding rail sections. The exception is with fishplates having very large lower flanges, reported in particular by the South African Railways when the ratio of the fishplate and rail sections is 1.5.

For the moduli of resistance and moments of inertia the proportion is much lower, being about 0.30 to 0.40 in general. It is as much as 0.46 on the Portuguese Railways, 0.44 on the Swedish Private Railway Union, 0.52 and 0.57 for the 133 and 155 lbs. rails of the Pennsylvania Railroad, and even 1.00 for the South African Railways.

Generally, the arrangement of the fishbolts depends on the arrangement of the rail fastenings on the sleepers, so that maintenance and tightening up can be done separately in each case. Opinions are very divided as to whether the nuts should be placed on the inside or outside of the track. It seems to us simpler and without drawbacks to have them on the inside.

The slope of the fishplate surface is generally the same under the head and on the foot. Some railways use different slope, either a greater or lesser slope under the head. The following results are found :

Under the head :

10 railways, slope of 1/3  
4 railways, slope of 1/273  
1 railway, slope of 1/2  
6 railways, slope of 1/4  
1 railway, slope of less than 1/4

At the foot :

7 railways, slope of 1/3  
2 railways, slope of 2/273  
1 railway, slope of 1/2  
9 railways, slope of 1/4 or 1/363  
3 railways, slope of less than 1/3.

The result of the fishplating should be to bring the running surfaces of the rails into contact as perfectly as possible. The Railways did not give many details on the

tolerances allowed in the case of new rails. Some of them chamfer the ends of the rails in order to prevent burrs forming at the joints. When the rails are worn, various methods are used to make good the wear of the fishplate surfaces : reforged or re-stamped fishplates — appropriate packings.

The wear of the upper part of the head is being made good to an increasing extent by welding on additional metal, the most widely used method being arc welding.

To prevent premature wear of the ends of the rails, some railways heat treat them; if certain precautions are taken, the results can be valuable.

The desire to obtain perfect coincidence of the running surfaces of the rails has led the S. N. C. B. and Netherlands Railways to design the so-called « perfect joint » which is excellent in itself, but involves higher costs for additional welding.

With the usual joint arrangement, devices are provided to enable the ends of the rails to expand. The « permissible expansion », i.e. the maximum gap between the two rail ends is a function of the difference between the diameters of the fishbolts and the holes drilled in the rails and in the fishplates, taking into account the differences there may be in the readings for drilling the rails and fishplates.

The permissible expansion varies considerably. It varies from 9.6 mm (0.378 in.) (Pennsylvania) to 24 mm (0.985 in.) (Danish State).

To appreciate the reason, it is obviously necessary to take the length of the rails into account. With the exception of the Pennsylvania and Victoria Railways which use fairly short rails, 12 and 13.7 m (39 and 45 ft.) with possible expansion of about 10 mm (0.394 in.), on most railways with 18 to 24 m (59 to 79 ft.) rail, the expansion allowed is of the order of 13 to 15 mm (0.51 to 0.591 in.).

It exceeds 20 mm (0.787 in.) on 3 railways :

S. N. C. F. : 21 mm (0.827 in.);

Swedish Private Railways: 22 mm (0.866 in.);

Danish State Railways: 24 mm (0.945 in.).

It is curious to note that most railways have obtained fairly large permissible expansion by increasing the diameter of the holes in the rails, the diameter of the bolt remaining fairly constant at 24 to 25 mm (0.945 to 0.984 in.), whereas the S. N. C. F. on the contrary has reduced the diameter of the bolt to 20 mm in order to be able to reduce the size of the hole in the rail to 23 mm (0.906 in.) (instead of 30 and 35 mm (1.181 and 1.378 in.) for most of the railways). This makes it possible to reduce the wear of the rail in the fishplating area and delays the formation of cracks; it also makes possible a better utilisation of the elasticity proper to the metal of the bolt which works at a higher value. The Private Swedish Railways have also adopted a bolt with a diameter of 22 mm, a little smaller than the usual diameter of 24 to 25 mm.

The Report covering the English speaking countries by M. CROOM-JOHNSON reports a few examples of the use of elliptical holes, of 27 to 30 mm (1.063 to 1.181 in.) for the small dimension and 30 to 38 mm (1.181 to 1.496 in.) for the large. It does not appear that the permissible expansion has been taken into account in the calculation. It is possible, though this was not precisely stated, that these elliptical holes are merely intended to prevent the bolts from turning.

Most railways mention the value of elastic arrangements to prevent the bolts getting loose and most of them use spring washers of the GROWER type, and some of them double spiral elastic washers. The British Railways do not use any device to prevent the bolts getting loose. The South African Railways use locking-nuts.

Elastic fishplates are not widely used. Apart from the C type fishplate of the Belgian Railways which, to some extent, form elastic arms, only the French Railways report interesting trials of an entirely elastic fishplate known as the « DURAND »

fishplate formed of a kind of packet of plate springs.

There is nothing special to report concerning the information supplied in connection with the manufacture of fishplates which are made of ordinary steel rolled hot, with a tensile strength varying between 42 and 65 kg/mm<sup>2</sup> (26.67 and 41.27 tons per sq. in.) approximately. A few railways use heat treatment. Most often the fishplate surfaces are not machined.

Nor is there anything special to report as regards the tests which are of the classic types (tensile, bend, hardness, etc.) and the conditions for inspection of the fishplates. No railways report trials carried out on the whole of an assembled joint.

Nearly all the railways make a systematic inspection of the joints which are completely dismantled, but the periodicity varies from one to several years; during this operation the wear of the fishplate surfaces is made good by the methods reported above: the use of restamped fishplates or metal packings of suitable size.

The Italian Railways report the repair of cracked fishplates by welding.

The maintenance of the level of the joint must be done with great care. A certain number of railways carry out a special levelling of the joints apart from the systematic overhaul of the track. In particular those railways using measured shovel packing report the good results obtained by specially packing the joints.

The insulated joint which is being used to an ever greater extent with the use of track circuits for signalling is undoubtedly a weak point, requiring very careful maintenance.

The most usual method is to insert between the fishplates and the rail packing pieces of insulating fibre 3 mm (0.118 in.) thick, between the 2 rail ends fibre plates of the same profile, and fibre sleeves and washers as well between the bolts and the fishplate holes or rail holes.

Some railways have adopted fishplates

made of hardwoods or impregnated with synthetic resins which, with improved manufacturing methods, have given increasingly good results (Austrian Federal Railways— Belgian National Rys.— S. N. C. F.— British Railways— London Transport Executive).

The British Railways report a special joint made up of stamped parts assembled with insulating inserts.

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## SECOND PART.

### **The use of long welded rails.**

The second part of the reports dealt with the use of long welded rails, i.e. rails longer than those normally rolled, built up by welding together standard rails.

On most of the railways, the rails are rolled in lengths of 18 or 20 m (59 or 66 ft.).

In some cases they are 27 to 36 m (89 to 118 ft.) long :

27 m (89 ft.) : Belgian 50 kg (33.59 lbs. per ft.) rail;

30 m (98 ft.) : Austrian 49 kg (32.92 lbs. per ft.) rail;

36 m (118 ft.) : Italian 49 kg (32.92 lbs. per ft.) rail;

36 m (118 ft.) : Swiss 46 kg (30.91 lbs. per ft.) rail.

On the other hand some railways always use short rails, 12 to 13 m (39 to 43 ft.) long, particularly the American Railways.

There seems to be a general tendency to extend the use of longer rails, obtained by welding, either in the shops before they are laid, or on site; in the former case electric welding is generally used, and in the latter, aluminothermic welding. We will not deal with the different methods used, which would be a digression, but suggest that the Permanent Commission retains this question for examination at a future congress.

Two points were brought out by the investigation undertaken : the ever increasing use as a standard practice of longer rails than can be obtained by rolling and a few tests made by some railways of very long rails, which practically amount to tests of doing away with joints altogether.

As regards the long welded rails used as a standard practice, we will leave aside those laid on metal bridges. The general tendency is to weld the rails from one end of a bridge to the other; but the problem is a special one in this case, since the bridge itself undergoes expansion and there is no fear of deformation of the track so long as the welded track is connected to the ordinary track by an expansion device enabling the rails to follow the deformations of the bridge itself.

In tunnels where there are practically no variations in the temperature, it is becoming more and more the practice for railways to weld the rails from one end to the other, no matter how long the tunnel is. In this way welded lengths of several kilometres have been obtained. Some railways provide a few rails of increasing length at the entrance to the tunnel, and of decreasing length at the exit; this does not seem to be really necessary, and many do not do so.

On station sidings, most railways apply the same rules as for the main lines on the open road, which will be dealt with below. Some however profit by the fact that the track is more rigidly encased in the ground and can therefore support higher stresses, even with a relatively light superstructure, so that lengths of some hundred yards or so are allowed.

On the main lines in the open road a certain number of railways now make it a practice to lay 36 to 60 m (118 to 197 ft) long rails, or even longer (82 m [269 ft.] on the Victoria Railways and 91 m [299 ft.] on the London Transport) without any special expansion devices at the joints. It is only possible to do so on condition on the one hand of getting rid of the regul-

ations for determining the play in the joints dependent upon free expansion of the rails, and on the other hand by so making the superstructure that it is strong enough to stand a certain amount of stress due to expansion.

On the first point all the railways are unanimous in recognising that the elongation of the track due to a rise in the temperature is much less than that resulting from the free expansion of the rail metal.

On the second point, it appears that so-called strong superstructures, especially with « indirect » rail fastenings (sleepers with sole plates fastened separately) or else the use of elastic spikes make it possible to use longer rails.

Opinions are divided concerning the value of anti-creep devices. Some railways have given up using them altogether, whilst others use them systematically, even on a large scale (Algerian and Swiss Railways). Others, finally, only use them on track with direct fastenings, or in parts of the line subject to creep.

The sleepering, i.e. the number of sleepers per km appears to be the same in the case of track made up of long rails as on the ordinary lines. With the exception of the light sleepering of 1 250 mentioned by the Franco-Ethiopian Railway, the figures quoted vary from 1 400 to 1 657. Some railways put the sleepers closer together at the welds, like at the joints; others, the greater number, use the same sleeper arrangement throughout.

No mention was made of any special devices to anchor the track to the bed.

The ballast is generally of broken stone; all the railways appear to take care to use carefully selected ballast of small size. The reporters did not mention any special arrangements as regards the profile of the ballast. In our opinion in the case of long rails which are stressed under certain conditions, it is essential for the profile of the ballast to be sufficiently wide and abundant.

Several railways have undertaken trials of very long rails, of at least 100 m (328 ft.) and even several hundred yards long: we may mention in order of size:

— the South African Railways have laid some rails of 146 m (479 ft.) and one of 292 m (958 ft.) with ordinary joints;

— the Italian Railways have laid a 276 m (806 ft.) long rail and one 425 m (1 394 ft.) long on a masonry bridge (direct and indirect fastenings on wood sleepers);

— the French Railways laid several trial sections in 1949 with 220 to 280 m (722 to 919 ft.) long rails, with various types of rails, sleepers and fastenings;

— The Swedish Secondary Railways have under trial a 1 060 m (3 478 ft.) long rail (direct fastenings with bearing plate) and the Victoria Railways a rail 1 447 m (4 747 ft.) long.

These rails, except those of the South African Railways, are laid with expansion joints of very similar kinds, consisting of a switch blade shaped part which can slide along a stockrail.

All the trials have given encouraging results, and no serious drawbacks have been experienced. Generally it is found that the centre portion of each long rail does not show any tendency to move, and at the ends the expansion is only felt over a few dozen yards.

It can therefore be hoped that these trials will prove that jointless track is not more subject to deformation under the effect of stresses (and in fact is probably less so) than track with fishplate joints. Obviously it is impossible to go on indefinitely without any joints, as it is necessary to provide transitions at the track installations and breaks in the track circuits, but the trials in hand should make it possible to decide what devices should finally be retained at the ends of these very long rails. They will also make it possible to define the steps to be taken in case a rail breaks at a temperature considerably lower than the temperature at which it was laid, whereas

the tractive efforts exerted in the rail tend to cause dangerously wide gaps.

The considerable advantages obtained by using long rails without joints as regards the maintenance of the permanent way and rolling stock, and the comfort of passengers, are such that they amply make up for the additional cost involved in laying and maintaining these long rails. Moreover, only the Swedish Railways have reported higher maintenance costs than for the standard track, but the trials are too recent for any definite conclusions to be drawn.

It would obviously be of great value to know for certain the stresses which the track can withstand owing to a rise in temperature, without risk of deformation. The information collected in this connection is rather divergent: they give either the maximum compression of the rail (of the order of 40 to 50 t per rail, and even more):

— or per  $\text{cm}^2$  of the rail section, which seems to be more accurate (can reach a maximum of 500 to 1 000 kg (3.18 to 6.35 tons per sq. in.);

— or more per  $\text{mm}^2$  of section and per degree of variation in the temperature (0.150 kg to 0.200 kg and 0.250 (213.35 to 284.5 and 355.58 lbs. per sq. in.) per degree centigrade);

— or the resistance of the track to sliding over the ballast with wood sleepers (Belgium) or metal ones (Switzerland) (200 to 500 kg per m [134.38 to 335.96 lbs. per ft.] per rail). The Italian Railways give a figure of 600 kg (359.28 lbs. per ft.);

— or the resistance to sliding between the rails and sleepers (the Belgian Railways got figures of the order of 2 000 kg (1 343.87 lbs. per ft.) in the case of fastenings with clips, i.e. much greater than the resistance to sliding of the sleepers on the ballast).

It would be interesting for trials and measurements to be made, completed, and above all co-ordinated in order to have more complete and accurate details available on the subject.

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### THIRD PART.

#### **The joint gap in terms of the temperature.**

The three reporters agree in pointing out that the regulations established by the different railways for the joint gaps to be provided in terms of the temperature tend to diverge more and more from the law of free expansion.

It is unanimously recognised from experience that the rail under the influence of a temperature rise does not expand as much as it would if it were free; the more solidly it is attached to the sleepers and the more firmly the latter are anchored in the ballast, the less is the expansion. Again the rail will shrink less under the effects of a fall in temperature. In addition, after variations in contrary directions, it does not at once return to its initial state. Its condition, at a given moment, is a function not of the temperature of the rail, but of the directions of the variations in temperature which it undergoes—and also of the traffic it carries. This fact has been clearly shown by some experiments especially by the Swiss Federal Railways.

If the regulations given are examined more closely, often in the form of tables, by the railways consulted, they can be classed into two categories:

*a)* those concerning relatively short rails, of a maximum length of 18 m (59 ft.), but usually only 12 m (39 ft.).

The rules are more or less based on the law of free expansion; in fact they are old rules which it has not been found necessary to modify, as the maximum gaps are always relatively small, being 18 to 15 mm (0.709 to 0.591 in.) under the worst conditions;

*b)* those concerning long rails, at least 24 m (79 ft.) long, which must necessarily set the law of free expansion aside. To prevent the joint gap becoming too great at low temperatures, it is admitted on the one hand that the variation in the gap is less than it would be if the rail expanded freely, and on the other hand, that the

gap can only close at a lower temperature than any the rail is likely to have to stand, so that it is submitted to a degree of stress, which increases according to the extent the temperature rises above the temperature at which the gap closes.

The maximum joint gap does not exceed 20 mm (0.787 in.) even with 60 to 72 m (197 to 236 ft.) long rails, and the gap is closed at temperatures of about 30 to 35° C (86 to 95° F) (the Swiss Federal Railways are considering 72 m long rails with the point gaps closed at 26° C (78.8° F).

Most of the railways measure the temperature on the rail—some have not given any precise details—only the Indian Railways take the temperature of the air into account.

To establish the rules concerning the joint gaps, most railways go by experience and continual observation of the track in service—especially in the case of relatively short rails which we classified in category *a*).

On the other hand most railways which have laid rails longer than 30 m (98 ft.) have made calculations and trials, as reported by the different reporters, intended to determine the stresses mentioned in the second part. We would refer the reader to the information given on this subject in each of the reports; we will simply state that most of the railways did not give any precise details about the methods of calculation used.

As regards maintaining the joint gaps in service, all the railways agree that variations arise due to very diverse causes, and it is impossible to maintain permanently the original accurate distribution.

As for the tolerances allowed, many railways gave no details. It seems sufficient to do as many do and fix the length of a section on which the total joint gaps must more or less correspond to the theoretical total; the gaps are only adjusted when they are found to vary too much from the regular figure.

It appears advisable to make the neces-

sary checks each year, before the hot weather, especially in the case of lines subject to creep.

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## SUMMARIES.

### FIRST PART

#### **Fishplated rail joints.**

1. It is apparent from a study of the reports received that there has been no considerable modification to the traditional fishplated joint, which consists of two fishplates, short or long, strengthened to varying degrees by lower or upper ribs, and held in place by bolts through the web of the rail. Complicated arrangements to provide a continuous running surface to the rail at the joint are not found in use to give the advantages hoped for by their inventors. Slant cutting of the rail ends is not favoured in current practice.

2. To avoid excessive fatigue in the constituent parts of the joint, it is usual to reduce the sleeper spacing adjacent to rail ends. The most general practice is to support the rail on two independent sleepers closely spaced, in preference to a double sleeper. As to the joint supported on a single sleeper, this now seems to be falling into disuse except in the United States where, from information received, it is still widely practised.

3. The most general arrangement is for joints to be opposite each other. Whilst the use of joints out of square or staggered by half a rail length continues to be employed in some instances on sharp curves to assist in the maintenance of alignment, the use of staggered joints elsewhere which was once fairly frequent practice has gradually fallen into disfavour, probably because of the swing which they induce in rolling stock on tracks where the rail length is comparatively short. On modern track, however, with longer rails it would seem that better results can be obtained from the use of staggered joints, and it would be of

interest, therefore, to renew experiments in this direction.

4. From the reports received, there does not seem to be any advantage in equating the section modulus of the fishplates with that of the rail.

5. To allow expansion at the rail ends, the holes in the fishplates and the rail must be larger than the diameter of the fishbolts.

Up to the present the general practice has been to make larger holes in the rail than in the fishplate, to minimise the weakening of the latter. On the other hand, it would seem that the adoption of smaller holes in the rail would reduce the risk of cracks which often commence at fishbolt holes; the use of oval holes in the fishplate would then allow the vertical dimension of the holes to be kept to a minimum.

6. The use of fishbolts of a relatively small diameter not only avoids having large holes in the rail and fishplate, but also makes the maximum possible use of the elasticity of the metal of the bolt.

7. It does not seem advisable to support the joint by means of a fishplate formed to act as a bridge.

8. The surfaces by which the fishplate makes contact with the head and the foot of the rail must be inclined to give a wedge effect and to allow for the taking up of wear. The most common practice is for the fishing angles to have an inclination of one in three at both the head and the foot of the rail.

Some systems have adopted an inclination of one in four, others a steeper inclination up to one in two, and sometimes the inclination differs at the head from that of the foot. There do not seem to be any particular advantages, however, in these variations.

9. Fishplates are generally made of ordinary rolled steel, having an ultimate

tensile strength slightly less than that of the rail. Some systems employ heat treatment but this practice does not seem to be increasing. The tests specified vary somewhat but offer no points of special interest and it is assumed that existing specifications give satisfaction.

10. Perfect alignment of running surfaces of the two rails meeting at the joint is of great importance. Rails should therefore be correctly matched when they are laid, and if possible rails from the same ingot should be placed together. The so-called « perfect » joint of the Belgian Railways is of great interest, but this is rather costly on account of the subsidiary welding which is involved.

11. Correct alignment of running surfaces of the rails in service can be obtained by shims of appropriate thickness, inserted between the fishplates and the head of the rail at the fishing angles. Specially forged fishplates are also useful for this purpose but are less exact.

12. The more rapid wear at rail ends, resulting from wheel impact, produces battering and burring over of the top surface. Some systems chamfer the rail ends so that burrs do not form too quickly. Ends can be built up by welding to restore a smooth running surface and to allow rails to remain longer in the track. Hardening of the metal by a suitable heat treatment can be expected to reduce these troubles at rail ends provided no appreciable brittleness results.

13. The use of spring washers to prevent slackening of fishbolt nuts is likely to have appreciable effect in reducing the labour of maintenance.

There does not yet seem to have been close investigation of the possibilities of the elastic fishplate. Where, however, fishplates with spring extensions at the ends have been used, useful results seem to have been obtained.

14. Careful attention to the level of joints increases their life. It is generally recog-

nised that joints should be attended to more frequently than the rest of the track and at least once a year; systematic packing of joints with small size stone ballast appears particularly satisfactory.

15. Insulated block joints present difficulties which can be reduced by the use of fishplates made entirely of insulating material with sufficient mechanical strength; up to the present bakelised wood seems the only material to give reasonable satisfaction.

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## SECOND PART.

### Long welded rails.

16. It has been learned from experience that rails of a length up to 300 ft. can be laid in the open in main lines without special provisions for expansion.

17. Opinion is divided on the necessity to provide special devices for fixing rails to sleepers. It is quite evident that the rails must either be permanently held down tightly or must be fixed by a spring device which creates a permanent pressure between the rail and the sleeper.

18. The number of sleepers per mile, on tracks with long rail lengths, varies considerably on different systems. Some consider that it is advisable to adopt a rather close sleeper spacing.

19. Neither anti-creep devices nor rail anchorages to the formation appear to be necessary to avoid creep of long rails.

20. The sleeper spacing at welded joints can be the same as in the centre of the rails.

21. In stations rails up to 330 ft. long can be laid in the ordinary way and no special precautions are necessary in regard to the attachment to sleepers or the fishing at joints.

22. In tunnels, where temperature variations are small, the rails can be welded

from one end to the other. There does not seem to be any need to employ gradually reducing lengths of rail between the long welded lengths and the normal track in the open.

23. The material and the cross section of the ballast formation of tracks with long welded rails is of great importance; to preserve alignment, particularly on curves, a good shoulder of ballast at the ends of the sleepers is essential.

24. Some systems have already carried out tests in the open with rail lengths of several hundred yards and obtained encouraging results; it is very desirable that such tests should be continued on a wide scale.

The elimination of impact at rail joints is certainly a source of considerable economy both in maintenance of track and of rolling stock, it also adds considerably to comfort.

25. It should be possible in the near future to determine from experience the type of joint (ordinary or special) to be employed for joining long rail lengths together, or connecting these to junction work and insulated block joints, etc.

26. Theoretical studies and the tests which have been made give varying results for the forces in the rail and the resistance of the track as a whole to these forces. It would be advantageous if these studies and experiments were continued on a uniform basis with common and well defined terms, so that the results could be easily compared. These should be concentrated on the actual tensions and compressions in the rails at different temperatures with different types of track. It would also be useful to find out by experiment the maximum resistance which different types of track can develop against movement as a result of the forces in the rail. Such studies and tests should enable a decision to be made as to the best temperature at which long rails should be laid.

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## THIRD PART.

**Rail gaps in relation to temperature.**

27. The general experience acquired is that the gaps between rails can be less than those theoretically calculated on a free expansion basis — in fact they can be reduced to a half or even less. The more the type of track resists creep, the smaller the gap can be.

28. Unless special arrangements are made for the joint, this is a weak point in the track which may be the origin of a buckle. It is therefore important that the play

allowed for expansion, having regard to the type of track concerned, is not all taken up at too low a temperature, otherwise there is risk that excessive forces will arise in the rail. In the course of maintenance work, and particularly before the first warm weather of the year, the rail gaps should be restored to normal. It is, however, permissible to allow some tolerance in the gaps compared to that provided at the time of laying.

29. Checking of joint gaps should be done at times of day when the temperature is not particularly high.

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### QUESTION III.

## New technical methods adopted for the design and construction of large marshalling yards.

### Lay-out and equipment :

**Side and importance of siding groups ;**

**Lay-out of connections at entrance to groups ;**

**Longitudinal and cross sections ;**

**Braking installations (Retarders) ;**

**Control of point (switch) operation ;**

**Telecommunications ;**

**Lighting ;**

**Staff buildings, etc,**

by M. MARCHAND,

Special Reporter.

The question about the technique adopted in the construction of large marshalling yards was the subject of the three following reports :

Report (America (North and South), Burma, China, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan), by J. I. CAMPBELL, and J. W. WATKINS (See *Bulletin* for April 1950, p. 483);

Report (Austria, Belgium and Colony, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Jugoslavia, Portugal and Colonies, Rumania, Spain, Sweden and Turkey), by J. VAN RIJN (See *Bulletin* for April 1950, p. 431);

Report (Denmark, France and Colonies, Italy, Luxemburg, Netherlands and Colonies, Norway, Poland, Switzerland and Syria), by MARCHAND (See *Bulletin* for April 1950, p. 363).

The International Railway Congress Association dealt with the construction of large marshalling yards in 1925 <sup>(1)</sup>, and

with the installations of shunting yards in 1930 <sup>(2)</sup>, so that the Reporters considered that their investigation should cover the technique applied during the last twenty years, and they asked the Railway Administrations to supply them with useful data (plans and characteristics of the traffic) about their large marshalling yards built or modernised since 1930.

The enquiry covered a total of 60 marshalling yards, most of which deal with a peak daily traffic of more than 2 000 wagons; 10 of these yards deal with a traffic of more than 3 000 wagons; the yards at Toton Down (Great Britain) and Enola (U. S. A.) have a peak traffic of 4 500 wagons.

We have not overlooked the fact that many other marshalling yards have been built since 1930, in Germany for example, as well as in the United States. Messrs CAMPBELL and WATKINS endeavoured by going through various documents of

<sup>(1)</sup> Special Report by Mr. W. SIMON-THOMAS. (*Bulletin* for June 1925, p. 2098.)

<sup>(2)</sup> Special Report by Mr. C. R. BYROM. (*Bulletin* for May 1930, p. 1437.)

American origin, to complete the data supplied by the Pennsylvania Railroad, the only Company who replied in time, and in this way collected a great deal of interesting information concerning the techniques applied in the United States.

In any case, the number of marshalling yards about which concrete details were collected is sufficiently large for it to be possible to derive much useful information therefrom and prepare summaries of a sufficient general bearing.

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Perusal of the three Reports shows that there is a very great similarity in the constructional characteristics of large up-to-date marshalling yards; the most diverse problems regarding the layout of the sidings, the braking, operation of the points, etc., have been solved in a similar fashion in the different countries, often in a completely identical way. The principles applied are, in general, those laid down by our predecessors, which were the subject of the Summaries of the London and Madrid Sessions to which we will sometimes have to refer.

It must not be concluded however that no progress has been made since 1930; if, at that period, the general principles were already well defined, the conditions of application were rather more uncertain, and extensive experience was still lacking on many points; this can now be considered as having been acquired; it has moreover been enriched either by certain improvements made in the layout of the installations, or by the introduction of new equipment which industry has made available for use by the railways, notably in the field of electrical installations.

The general principles applied in the construction of marshalling yards are based on a common idea: that of increasing the output of the installations, with the double object:

— on the one hand, of reducing the cost per wagon shunted, the question

being dealt with under Question VII of the Rome Congress as regards the organisation of the marshalling yards services;

— on the other hand, to increase the output of the installations, and in consequence their daily capacity; from this latter point of view, the modernisation of marshalling yards is particularly fruitful as far as the operating is concerned, as it makes it possible to close down the secondary yards by concentrating all the traffic in the main yards. It also makes it possible, on account of this concentration of the wagons, to make up the through trains and suppress the stops at intermediate yards, with all the resulting consequences as regards lower risk of damage occurring, speeding up the transport, and improving the turn round of the rolling stock.

Consequently, whether it is question of the choice of site for a marshalling yard, or of determining the number and size of the groups of sidings, the layout of the traffic lines or the lead-ins to the sidings, all these problems are dominated by the needs of the Operating Department. If the present question concerning the construction of marshalling yards had been set from the point of view of the technical angle of civil engineering, it still could not be disassociated from the point of view « operating », whose requirements are the predominating factor in its very conception.

The Report of Messrs CAMPBELL and WATKINS is quite definite on this point:

« As the department responsible for « operations » is the one which normally has to justify schemes intended to facilitate the efficient working of traffic, it is desirable that the Operating Department should advance the preparation of a scheme to the extent practicable before the Engineering Departments commence work on any plans or estimates.

» All aspects of yard operating perfor-

mance, together with study of developments generally, also close contact with Engineering Departments, should be handled by experienced staff within the Operating Department, who should specialise on this feature where not already done. »

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Each proposal to modernise or build a marshalling yard is a special case requiring special study, taking into account the numerous operating and technical requirements, which should enable an economic balance sheet to be drawn up.

In most countries, the railways have developed in such a way that the number of marshalling yards in existence is abundantly sufficient or even sometimes excessive; consequently it is usually a question of modernising those that are well sited geographically within the frame of the general organisation of transport; but such modernisation often comes up against difficulties in practice; the marshalling yards are in the middle of cities, their extension comes up against many obstacles and depends upon the configuration of the site available, which may make it necessary to adopt a layout which is not altogether satisfactory from the point of view of output, or insufficient from the point of view of capacity.

In addition, the different phases of alteration involved generally increase the cost of construction; they may also give rise to restrictions and extra costs for the Operating Department.

It is sometimes advantageous in order to escape such inconveniences to move the marshalling yard out of the town, with the essential reservation that it is possible to solve the transport problems that this will involve and if needs be house the staff: the new site for the marshalling yard is then decided in terms of the connections with the different feeder lines, and the availability of a sufficiently large site of suitable profile, although the use of up to date mechanical equipment makes it possible to reduce the cost of earthworks.

From the Reports presented, the following tendencies are seen as regards the general arrangement of marshalling yards built or modernised since 1930 :

- the marshalling yards are generally sited parallel to and beyond the feeder railway line; in certain special cases they are sited in between the main lines; exceptionally, certain marshalling yards have been built at right angles to the feeder railway line, with which they are linked up by junction lines;
- no double marshalling yards have been built, i.e. with complete reception, marshalling and making up groups for each direction of traffic; generally, it is relatively costly to operate such double yards; the increase in the capacity of single yards has moreover been pushed up to more than 4 000 wagons, the limit of capacity after which it is necessary to provide double marshalling yards;
- only one yard has been built on a continuous falling gradient; such yards have no special advantages from the operating point of view as the shunting is relatively slow; the daily capacity is therefore greatly reduced. Moreover, in countries where the wagons are not fitted with side hand brakes, the braking and stopping of the wagons involves the employment of additional staff, which does away with part or all of the savings obtained by not having to use shunting engines.

The construction of marshalling yards on a continuous falling gradient should not be considered therefore except in exceptional cases where the natural profile of the site makes it necessary.

#### Groups of sidings.

If reception and marshalling groups are systematically provided in all up to date

marshalling yards, the same cannot be said for the other groups of sidings: departure, making up or relief, the use of which depends upon the characteristics of the work of the yards and that of the traffic of the adjacent lines.

Out of the 60 yards covered by the present enquiry, it appears that about half are equipped with departure sidings, amongst them in particular most of the yards in Belgium, Switzerland and Italy; 20 yards are equipped with special making up groups of sidings, and 10 yards, most of them in France, have relief sidings.

Apart from material considerations, especially the configuration of the site, which may make it impossible to adopt the most satisfactory arrangements, the siting of the various groups of sidings in relation to the marshalling group must be gone into from the angle of economising in transfer shunts.

From this point of view, all the reporters are agreed that it is an advantage to have:

- the departure group as an extension of the marshalling group;
- the special group for geographical making up near the lead in to the marshalling group opposite to the shunting, and preferably on the sides of this group;
- the relief group alongside the marshalling group near the main lines; however, when relief operations do not include the exchange of wagons with the marshalling group, the site chosen for this group will be subordinated to the need to assure good connections with the locomotive sheds.

The number of sidings in the different groups is fixed by the Departments using them in terms of the requirements and place available; according to Mr. VAN RUN's Report an average of 4 to 5 trains per day per siding can normally be estimated for the reception group, but it is not possible to make similar estimates in the case of the other groups whose user varies a great deal.

As regards the lead-in to the groups and the connecting sidings, all the reporters insist upon the need to adopt an arrangement that will reduce the time spent in shunting, apart from the actual shunting itself:

- on the one hand, by eliminating as far as possible all risk of interruptions to the shunting due to other train movements, especially the reception or departure of trains;
- on the other hand, by limiting to the strict minimum the length of the run in the shunting areas, especially where the shunting takes place at a slow pace, for example in the access zone to the shunting hump; for this purpose it is highly recommended to simplify the installations of the sidings so that only the absolutely necessary equipment is retained. For example, double humps at different levels, winter-summer, have been practically given up in yards equipped with track brakes.

On the other hand, although this increases the length of the lead-ins, sidings by-passing the hump are generally provided because they are essential for the operating.

The results obtained in the sense of improving the output of shunting is one of the striking improvements effected since 1930 in the design of marshalling yards; the invention of track brakes and the application of the principles laid down at that time for the construction of lead-ins to large capacity groups of sidings has made it possible to provide shunting yards whose working cadence may be as high as 6 to 8 wagons per minute. The effective realisation of such working cadences has enabled the output of marshalling yards to be increased, but at the same time, has made the extent of idle time still more noticeable and has brought out the need to harmonise the whole of the installations in order to obtain the maximum output.

For example, in marshalling yards where

only a single shunting engine is used, a judicious layout of the installations will make it possible to save one minute in the time the engine takes to circulate between two successive shunts, which will mean the same increase in the output as is given by increasing the average shunting cadence from 7 to 8 wagons per minute.

To sum up, it can be said, that, if before 1930, shunting generally was a bottleneck as far as the output of marshalling yards was concerned, the situation has undergone a complete reversal since then and it has been recognised as necessary to direct the efforts for improvements to all the installations apart from the shunting in order to increase the output, the efficiency, and, eventually, the capacity.

### Construction (layout, levels, profiles).

In most up to date marshalling yards, the Administrations have endeavoured to reduce the area of the lead-ins to the groups of sidings; in general they have adopted the classic arrangement of the so-called « balloon » shape, which has the advantage that the sidings (garages francs) of the lead-ins are on the same alignment, which facilitates considerably the work of the pointsmen and brakesmen. Most Administrations use the standard types of track equipment for the sidings, but Belgium and France have built special double symmetrical turnouts with a wide angle; Great Britain stipulates the use of triple turnouts with lapped points.

In the shunting lead-ins, the layout should be made as compact as possible; the determination of the height of the hump and the use of hollowed out profiles result from the principles laid down in the reports for the 1925 and 1930 Sessions, especially the very fully documented report of Dr. GOTTSCHALK (1930) (\*).

We will merely recall that the height of the hump should be sufficient to enable

the poor running wagons to reach the marshalling sidings, even under the worst atmospheric conditions; it depends therefore upon the resistance to rolling of the stock, the intensity of the winds blowing along the centre line of the yard and the length of run the wagons have to make in the entrance to the shunting group. On the other hand, in order to assure rapid separation of the cuts to be shunted and thus enable the distance between the hump and the first set of points to be reduced, it is desirable for the radius of curvature of the hump to be as small as possible with a steep initial gradient to begin with which then diminishes until after the brakes; there is a level section or very slight gradient.

If, however, the arrangements of the layout and profiles are based on the same principles, in actual fact some differences of application are found, which it appears interesting to mention :

1) the normal spacing of the tracks in the groups of siding vary from country to country within fairly wide limits; the free space between tracks for the staff to move between the rows of vehicles is :

- 0.66 m to 1.06 m (2' 2" to 3' 5 3/4") in Great Britain;
- 0.91 m (2' 11 7/8") in the United States;
- 1.40 m (4' 7 1/8") in most European countries.

The differences recorded do not appear to be due to operating conditions, nor the conditions under which the staff work in the groups of sidings, except in the case of the marshalling group where the wagons are closed up by means of tractors running between the tracks;

2) in all the marshalling yards, the profile of the entrance to the group of sidings below the track brakes is always so arranged that the wagons will not gather speed.

However, though certain countries make this area on the level (Switzerland, Italy), others provide a slight gradient, just suf-

(\*) *Bulletin* for January 1930, p. 309.

ficient to compensate the resistance due to the curve, or even a slightly steeper gradient intended to maintain the speed of good running wagons constant.

We stated in our report that in providing a gradient there was less risk of wagons stopping or running very slowly through ill-considered braking, but it seems better to have a level section, provided selected and carefully trained brakemen are available; the level section makes it necessary to let the wagons retain a fair speed after the retarders, which has the effect of increasing the distance between successive wagons and reducing the risk of overtaking and consequently increasing the shunting cadence;

3) limiting characteristics affecting the design of the layout (radius of curves) and profiles (radius of curves, maximum gradients, non-accelerating gradients (<sup>1</sup>), etc.), vary from country to country: the differences recorded can be explained to a great extent :

- either by the differences in climate, as wagons run better in the southern than in the northern countries;
- or above all by the differences in the characteristics of the rolling stock : for example in Great Britain, where many wagons have grease axle boxes, the non-accelerating gradient is fixed at 5 mm per metre (5 ‰), whereas in America where all the wagons are on bogies with oil axle boxes, the same gradient is 2 mm per metre (2 ‰).

We may report in this connection that the use of wagons with roller bearing boxes may have a considerable effect upon the installations.

(<sup>1</sup>) The so-called "non-accelerating" gradients are those where the good running wagons will not pick up speed; they are appreciably the same as those on which it is possible to leave wagons or rakes standing without having to take special precautions to keep them stationary, designated by the expression "semi-level".

In the same way, the types of shunting engines or train locomotives condition the admissible limits of the radius of the transition curves in plan and profile; it appears however that in Great Britain the Traction Services have considered this question very liberally, as the radius of curvature of the hump profile is relatively reduced and varies between 175 m and 230 m (574' 1 3/4" and 754' 7 1/8"), whereas in most other countries, the limits fixed are of the order of at least 250 m (820' 2 1/2").

However it may be, these considerations show that a comparison of the details of construction should only be made very circumspectly, and that it would be imprudent to apply the standards of one country in some other country without carrying out a preliminary examination;

4) some railways in the United States are the only ones to use lubricating devices to improve the running of vehicles through curves; the other Administrations consider that such devices have more drawbacks than advantages.

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We have no detailed commentary to make regarding track material : rails, sleepers, ballast, in which there has been very little evolution; the quality of these materials varies from yard to yard, and in different parts of the same yard, according to the wear to which the sidings are submitted.

The accentuation of fatigue effects due to the high output of modern marshalling yards and to the increase in the axle loads of locomotives and wagons, as well as the development of track circuits, justify the present tendency towards the use of better quality track material.

As regards the laying of the track, MESSRS CAMPBELL and WATKINS stress the fact that in many cases it is advantageous to carry out the work with the mechanised equipment used for replacing the track on the main lines, either to put down prefabricated sections of track, or to unload

ballast from hopper wagons or automatic unloading machines.

In the same way, it is advantageous to make use of up-to-date equipment for any earthworks needed : excavators, scrapers, compressors (*à pied de mouton*), etc.

All that is possible should be done to maintain the profile by correcting any falls, or by making the foundations and beds underneath the shunting humps of concrete; finally drainage must be provided when necessary to keep the formation of the sidings in good condition.

### Braking.

The evolution in the technique of equipping large marshalling yards has been characterised in the last decades by the development of the use of track brakes.

Amongst the 60 yards modernised since 1930, plans of which were sent in to the reporters, more than half have been equipped with brakes; but if the equipment realised in various countries like America and Germany is taken into account, it can be estimated that at least one hundred large marshalling yards are equipped with track brakes.

This is a decisive orientation which eliminates the uncertainties still felt in 1930, when the Railway Congress Association prepared the following summary (point 7) :

« The difference in conditions, capacity and weight of vehicles in general in the different countries, together with the fact that distant-controlled shoe or rail brakes are largely in their infancy, and are still in the process of development and improvement, and the lack of experience of them in certain countries, prevent any general conclusion being reached in favour of a particular type. »

In fact, mechanised skids did not develop, at least as the main braking equipment of large marshalling yards; in addition, certain types of equipment, such as the electro-magnetic brake, or wagon accelerators on which some hopes were based, never passed the experimental stage.

The track brakes now used can be divided into two types :

- direct acting brakes (Westinghouse, GRS), the use of which appears exclusive to America;
- self-tightening brakes (Froëlich, Saxby) used by the other Administrations.

Only France appears to have used both types of brakes.

The general characteristics are the following :

*a)* in the direct acting brakes, the jaws close up against the wheels with variable pressures depending entirely on the way they are controlled.

When conditions are equal, the live force absorbed is constant and independent of the weight of the wagon; the length of braking required increases consequently with the weight of the wagon braked.

The brakes, which are operated pneumatically or electrically, are of simple design; no foundations are required, and they can be installed on large radius curves;

*b)* in the self-tightening brakes, the jaws exert their force laterally, whilst taking a bearing directly or indirectly under the wheels of the wagons.

If the control pressure is sufficient, the wagon is lifted up and the braking effect is proportional to the weight of the wagon; the braking length required is therefore independent of the weight of the wagon braked.

For an equal braking length, self-tightening brakes are more powerful than the direct acting brakes used in Europe, because their jaws are raised when they are operated to the maximum height compatible with the clearance gauge of the lower details of the rolling stock; they act on the wheels at a higher level and consequently further away from the instant-

taneous centre of rotation of the wheels <sup>(1)</sup>.

Self-tightening brakes are fluid operated; water or oil; they are of rather complicated design and foundations have to be built for them; on the other hand, their consumption of current is relatively low (in France, it is less than one quarter of that of the direct acting brakes).

Track brakes of the two types have undergone various improvements since 1930, to eliminate the effects of bad weather, facilitate maintenance and reduce the corresponding costs; Great Britain has improved the foundations for Froëlich brakes and used oil operation; modifications have also been made in France to this type of brake to eliminate the disturbing effects due to large variations in the width of the types on account of the heterogeneous nature of the rolling stock.

In view of the insufficiency of information supplied and the difficulties of comparing prices as from one country to another, which are still further increased by the exchange rates, it was not possible to make a financial comparison of the capital cost and maintenance costs of the brakes used by the different Administrations.

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As regards the siting of the track brakes and their control posts, the techniques applied are very uniform, with however considerable divergencies in the United States.

In most countries, with short shunting leads and consequently limited hump height, a single row of brakes has been found sufficient, each brake controlling a group of about 8 sidings; in recent yards,

<sup>(1)</sup> The International Railway Union has undertaken an investigation tending to raise the clearance gauge of new wagons (axle boxes and rods) to make it possible to increase in the future the height of lift of the jaws of this type of brake and consequently to increase their power.

the brakes are operated by a single man installed in a tower on one side.

In the United States however, the shunting yards are generally equipped with 2 or 3 rows of brakes; towers on the side, each corresponding to one line of brakes, are responsible both for the brakes and the switches of the corresponding area; this arrangement can be explained by :

- on the one hand, the long lead-ins to the groups of sidings which involve high humps;
- on the other hand, because the brakes are of the direct acting type and a long braking length is required to absorb the live force of heavy wagons (large capacity bogie wagons).

Most Administrations moreover consider it essential to use hand operated skids in addition for those wagons which have not been sufficiently retarded, but no precise details are available of the provisions made in the United States in this connection.

Finally, it may be mentioned that investigations are being carried out in different countries to reduce the number of brakesmen required; in France the possibility of advising the brakesmen of the speed each wagon should have after being braked is under consideration; according to our information, in Germany a supplementary device is under trial which includes a brake on each marshalling siding, one hundred metres (328 ft.) from the lead-in siding (garage franc d'entrée).

### Centralised control of the points.

In this connection the Madrid Congress stated :

« The economies can be supplemented by grouping together the control of point or switch operation in the same location as the shoe or rail-brake control. It may be desirable that the points should be « quick-acting » and advantageous, at high capacity hump yards, for the points to be capable of being pre-set electrically and automatically changed by the vehicles themselves. »

All these principles have now become common practice; especially the automatic control of points which is the general practice, and has even been extended to installations without track brakes.

Automatic control as applied in most marshalling yards substitutes for individual control of the points route control which is generally effected by the hump post when the wagons run over it; the points are then operated automatically at the correct moment, the running of the wagons being controlled by means of the track circuits or similar devices. The result is that it must be possible to set up several routes simultaneously by the apparatus, the number being at least equal to that of the wagons likely to be running at one and the same time in the automatic switching area.

The apparatus used varies from the point of view of the consequences involved if two successive cuts overtake each other; with some arrangements, overtaking interferes with the succession of the routes for the following wagons; it is then necessary to have the matter put right by an employee.

Other more perfected arrangements, which can be considered as giving perfect automatic control, avoid this drawback.

Automatic control may only cover the points at the entrance to the shunting yard, but many Administrations prefer automatic control of all the points which under certain conditions makes it possible to do away with the marshalling pointsman (provided a perfect automatic control arrangement is installed).

In a yard fitted with brakes and automatic control of all the points, the different controls needed during shunting are :

- a) control of the brakes;
- b) control of the methods of communication with the shunting engines;
- c) control of the points and signals of the zone receiving the trains and the run-

ning of train locomotives at the same time as the shunting;

d) the control of the routes for automatic shunting;

e) individual emergency control of the marshalling points, should the automatic control temporarily break down.

These different functions are normally divided up amongst three men, the solutions adopted and consequently the arrangement of the control towers varying from railway to railway, and even from yard to yard; in some yards, especially when perfect automatic control is available, this number is reduced to a total of two men.

Certain Administrations, though not very many, provide for « storage » of the routes of the different cuts of each train; this enables a saving in the men required to give the route orders during shunting (function d), but makes it necessary to prepare a « cut » list and implies that it is the exception to make any changes thereto.

### Auxiliary equipment.

Auxiliary equipment such as telephones, teleprinters, pneumatic tubes, lighting, buildings does not differ much from that already in use in 1930, except for the application of the new techniques of acoustics and wireless communication.

The use of loud-speakers is extending because nowadays equipment is available that is both powerful and clearly audible; the last development in railway operation is the use of « talk-back » systems which enable the men out in the yard to exchange conversations with the men in the control posts even when they are not near the apparatus.

Many Administrations make use of wireless installations to provide communication between the shunters and engine drivers; these are short wave, about 1 m (3' 3 3/8"), sets with modulation of the amplitude, and frequency or phase, which can assure one way and two way communications.

They make it possible to improve the output whilst maintaining more complete and accurate liaison between the staff than optical signals, which have to be multiplied at heavy expense when the shunting makes use of several engines or when there is a large number of sidings in the reception group.

(Incidentally, it should be noted that the arrangements reported at Madrid for direct control of the shunting engines by the hump staff have not been developed.)

However certain Administrations point out :

- on the one hand, radio apparatus must be of very good manufacture to assure a semi-permanent service without too high maintenance costs;
- on the other hand, it would be desirable to have moveable equipment, which could be fitted on any locomotive at any time, since lacking this, it is necessary to install fixed sets on all the locomotives likely to be used for shunting in the marshalling yards.

Portable radio sets are also used to enable the men in the yard to communicate with the men in the posts; in the United States, the details of the composition of trains are listed in certain yards by dictaphones which record the information sent by the markers off by radio.

### Future prospects.

The techniques applied in the construction of modern marshalling yards make it possible to get very satisfactory installations from the point of view of output and capacity from the operating point of view. Experience proves in effect that it is possible with a single shunting yard to have a peak daily output of more than 4 000 wagons.

As regards output, and in particular the reduction in labour costs, important progress has been realised by the systematic application of all arrangements likely to

speed up the shunting and reduce the idle time; the extended use of track brakes and automatic control of the points has made it possible to replace a large staff by one or two men, working under excellent visibility and comfort conditions; the risk of individual accidents has been much reduced by this fact.

Does this mean that the railways are entirely satisfied? Without wishing to prejudice any innovations which may modify or even completely alter the techniques now applied, we think it necessary to insist upon the most interesting improvements which it would be desirable to make within the frame of present conceptions :

- as we have previously stressed, it is generally indispensable to have an auxiliary brakeman for wagons which have been insufficiently braked; as the number of brakemen is relatively large compared with the very reduced staff of the marshalling and hump control posts, it would be extremely desirable that the braking technique be improved and make it possible to brake every wagon to a stop, so that the brakemen would only have to intervene very exceptionally or should an accident occur;
- the cost of track brakes is relatively high and their application has been limited to date to large marshalling yards; it would be very interesting to have available simpler and less costly apparatus which would make it possible to extend the field of application of mechanisation to the average sized yards;
- it may be mentioned in addition, that certain Administrations are now making trials of apparatus to weigh wagons when passing over the shunting hump to discover any whose load exceeds the weight given by the consignor; the use of such equipment will make it possible to adjust the freight rates accordingly and make it unnecessary to provide weigh-bridges in the small stations.

### Summaries.

The following conclusions are proposed to the Congress of the International Railway Association.

#### General.

1. The methods adopted in the design and construction of marshalling yards are based on the fundamental principles laid down at the Congresses of London (1925) and Madrid (1930); they aim at increasing efficiency, reducing costs and enlarging shunting capacity by the application of « mechanisation » and the planning of rational lay-outs and profiles.

2. Each new scheme presents a particular problem, from the points of view of cost of construction and economy in working. It is desirable that the study of schemes should be advanced as far as possible by competent staff of the department responsible for operations, before constructional plans are prepared (commenced).

3. The modernisation of existing yards, often situated in congested areas, may present difficulties of realisation owing to the want of available space.

4. The construction of new yards involves the finding of suitable sites from the point of view of superficial area and contour; when the sites selected are remote from populated areas, it is necessary to consider means of transport and housing accommodation for staff.

5. Except where special cases or local circumstances render all other solutions impracticable, the construction of double yards, comprising two yards, side by side, each dealing with an opposing flow of traffic, is justified only when the number of vehicles to be dealt with exceeds the capacity of a single hump yard.

6. Yards on the gravitation principle, wholly or partially, are only constructed where a suitable profile exists.

#### *Location of groups of sidings and connecting lines.*

7. In addition to reception and sorting groups, which are usually laid out in sequence, large yards should have separate marshalling and departure groups, also « recess » facilities as necessary.

From the point of view of operating convenience, and expeditious transfer movements of vehicles, it is recommended that the following be provided :

- departure groups in continuation of the sorting group;
- marshalling group and recess lines at the sides of the sorting group.

8. The number of sidings in the different groups and their effective length are decided by the department responsible for operating, according to service requirements, taking into consideration future developments and having regard to the space available.

9. The arrangement of communicating and connecting lines, and the siting of the leads of the groups of sidings should be studied with the object of facilitating the movement of trains and locomotives so as to reduce to the absolute minimum interference between trains, locomotives and shunting operations. In these circumstances constructional works should be undertaken in order to eliminate the more restrictive cross-movements.

10. The risk of interference between shunting operations and trains can be appreciably reduced by the provision of independent facilities; at large yards the provision of direction reversing loops or equivalent facilities permits, in conjunction with the use of departure groups, of one-way working which facilitates operation.

11. The layout at the heads of the groups of sidings should be as simple as possible in order to reduce the length of shunt.

The provision of double humping lines at the same level enables an appreciable

reduction to be made in the length of the head of the reception lines nearest to the hump; it also affords the possibility of more continuous shunting when two humping locomotives are employed.

On the other hand humping lines at different levels (winter and summer) have the disadvantage of lengthening the layout and the length of shunt. Moreover they are unnecessary when the yard is equipped with rail brakes.

12. Subsidiary facilities should be incorporated for holding brake vans, locomotives, for the rapid repairs to vehicles and for re-adjusting displaced loads. These installations should facilitate working, but their existence should not, in any case, constitute a source of slowing down the flow of the sorting and geographical marshalling operations.

#### *Construction (layouts, levels, profiles).*

13. It is recommended that the heads of siding groups should be very compact, adopting for the layout curves of minimum radius compatible with free movement of locomotives and vehicles.

It is advisable to use for this purpose specially designed permanent way, particularly short symmetrical two-way leads.

14. It is desirable that in the body of the groups the sidings should be of straight alignment; the distance between sidings is determined so as to ensure the safety of staff working in the spaces between them.

15. Considerations of economy in installation and maintenance generally justify the use of recovered serviceable rails in the body of the siding groups and new rails of the type standard for main lines in the heads of the groups. In order to reduce the number of joints, rails in the body of the sidings are sometimes welded.

16. Ballast, the nature of which depends upon local or other sources of supply, is

generally placed on an underbed of permeable material. When the nature of the group necessitates it, a drainage system ensures the removal of surface water.

In track circuited areas, particular attention should be paid to ballast and drainage.

17. The reception group is constructed on a fairly level gradient, a short rising gradient approaching the hump being provided in order to permit the uncoupling of vehicles.

It is possible, in order to avoid earthworks, to allow an appreciable gradient between the reception group and the hump without however exceeding the capacity of the locomotives employed for hump shunting.

18. The relative levels of the hump and the sorting groups depend upon the drop necessary to ensure under all conditions the separation of vehicles by gravity.

19. In order to ensure rapid separation of cuts, the radius of the vertical curve of the hump should be small; further the profile between the hump and the head of the sorting group should be hollow and should include a steep initial gradient.

After this gradient, the profile should be such as to ensure in all instances adequate spacing of vehicles up to the braking zone. The brakes are established on a falling gradient in order to liberate easily vehicles which may have been stopped there.

20. The switching area beyond the rail-brakes should be on the level or on a slightly falling gradient — the gradient being then sufficiently reduced to prevent acceleration of good running vehicles.

Such a profile may permit, with experienced brake operators, of increasing the rate of shunting because it is necessary that the vehicles should have an appreciable velocity at the outlet from the brakes, with the object of increasing the distance between successive cuts, thus reducing the risk of overtaking.

21. It is recommended that the longitudinal profile of the sorting group should be hollowed — the ends presenting suitable gradients intended to facilitate the running of vehicles without risk of inopportune acceleration.

Steeper gradients should be provided on the outer sidings in order to compensate for curve resistance — the cross profile being thus slightly cambered.

*Railbrake and switching control.*

22. The technical development of equipment at large marshalling yards has been characterised in recent years by the increased use of railbrakes.

The design of railbrakes has been improved, in order to facilitate maintenance and reduce costs correspondingly, and, in certain countries, to overcome difficulties resulting from important variations in the width of wheel tyres.

23. With the object of keeping down the cost of equipment, it is possible to be satisfied with the installation of one set of railbrakes both for interval and distance braking; each railbrake generally serving a fan of eight sidings.

24. In installations of this type, the railbrakes can be operated by one man, located at the side at the head of the sorting group; supplementary braking of vehicles which have not been retarded sufficiently by the railbrakes is effected by means of either hand brakes on the vehicles, or by shoes manually placed, or possibly by mechanically operated shoes.

25. The movement of switches by quick acting motors controlled by track circuit or other equivalent apparatus, facilitates the work of the switch operators; it enables economies in staff to be made and increases the shunting capacity of the yards.

26. Apparatus for the automatic control of switch operation enables the rate of shunting to be increased. Their employ-

ment has become general and it has even been extended to yards not equipped with railbrakes.

27. Automatic switch control must enable the routes of several wagons to be recorded; it can be applied either at the head only of the switching area or throughout. In the latter instance, it is possible to dispense with a switching operator for the sorting sidings provided that devices can be incorporated to avoid incorrect routing of succeeding cuts in the event of one cut overtaking another.

28. Some Administrations include in the automatic switch operating system a storage apparatus which enables successive routes for the different cuts to be stored before the commencement of shunting.

*Auxiliary equipment*

(communications, lighting, buildings).

29. Electrically controlled indicators, or teletype apparatus, enable the hump post to indicate to the brake operator, and eventually to the switch operator, the destination and the nature of each cut; in certain instances such apparatus has avoided the necessity for the preparation of « cut » lists.

30. Out-door loud speakers are the most practical and most used means for the transmission of orders to the yard staff; « talk-back » loud-speakers give the same facilities by means of two-way communication.

Liaison between the shunting control points and the yard staff can likewise be effected by means of portable radio apparatus.

31. Communications between shunting control posts and humping locomotives are usually given by mechanical signal or for preference by the illuminated type of signal.

These signals should be repeated as necessary, either in elongated yards or in those yards worked by two locomotives.

At certain modern yards these signals are substituted by apparatus in the driving cab of the shunting locomotives, cab signals, carrier waves, or radio.

32. Wireless, which can be « one-way » or preferably « two-way » is developing progressively because it affords more complete and precise inter-communication.

It appears desirable in order to provide for the future, that the Railway Administrations should have the necessary wavelengths allocated to them by the appropriate authorities.

33. The economy of night operation depends upon the character of the illumination provided; this should receive special attention in the zones of intensive shunting or of movements in the zones of centralised switch and brake control posts.

Except in the case of yards subject to frequent fog it is advantageous to use powerful lights fixed at a considerable height; oblique lighting (floodlighting) by projectors enables a reduction to be made in the number of supports and to place them outside the siding groups.

34. The control posts for the switches and railbrakes should be sited and arranged in order to ensure the best visibility of the ground; they are generally elevated and provided with large bay windows and awnings.

35. Apart from the different buildings which it is an advantage to group, each yard requires a principal administrative and control building which is generally installed at the main centre of operation.

## SECTION II. — Locomotives and rolling stock.

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[ 625 .2 ]

### QUESTION IV.

## The comfort of passengers in coaches, railcars and electric motor coaches :

**Sound proofing;**  
**Lighting;**  
**Heating, air conditioning, ventilation, thermic isolation ;**  
**Upholstery;**  
**Running stability (type of bogie and suspension),**

by M. MARTINELLI,

Special Reporter.

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### Foreword.

The object of the present special report is to sum up briefly the three reports mentioned hereafter concerning the comfort of passengers, and to draw therefrom summaries concerning present tendencies in this field.

It is obvious that it is not possible to discover definite tendencies in each branch considered. In the case of many of the problems, it must be admitted that the solutions adopted are very various. This means that in such cases a completely satisfactory solution has yet to be discovered. It is nonetheless interesting to glance at the different tendencies and different solutions adopted in the case of problems of topical interest.

The competition of road transport moreover makes it necessary to undertake a more thorough and careful investigation into the methods of making the most of the intrinsic advantages of the railway compared with road transport. One of these advantages is the possibility of the railway offering greater comfort, especially in the case of travel by night and under unfavourable climatic conditions.

The efforts of the technical experts should therefore be directed towards providing an ever increasing degree of comfort, even if economic reasons militate against this. In actual fact, if economies are carried to the extent of seriously limiting the improvement of comfort, while railway transport would still not be made less expensive than road transport, there would be a risk of doing away with, in great part the very reasons why the public thinks it advisable to pay the higher cost of railway transport and its relative obligations.

The present special report is based on the three following reports :

Report (America (North and South), Great-Britain and North Ireland, Dominions, Protectorates and Colonies, China, Burma, Egypt, India, Pakistan, Malay States, Iraq and Iran), by E. F. LOQUET (See *Bulletin* for July 1950, p. 1597).

Report (Belgium and Colony, Denmark, France and Colonies, Luxemburg, Norway, Netherlands and Colonies, Poland, Switzerland and Syria), by O. G. WEBERG (See *Bulletins* for May 1950, p. 931; and for September 1950, p. 1995).

Report (Austria, Bulgaria, Finland, Greece,

Hungary, Italy, Portugal and Colonies, Rumania, Spain, Sweden, Turkey and Yugoslavia), by M. MARTINELLI (See *Bulletin* for September 1950, p. 1861).

### Remark.

As only some of the Administrations belonging to the International Railway Congress Association, who were called upon, replied to the questionnaire sent to them, it is obvious that our summaries regarding tendencies refer exclusively to those Administrations who sent in details and that, in particular, they conform strictly to such information and data.

### Sound insulation.

#### 1. Methods used to diminish the formation of noise.

The use of elastic wheels, with rubber packings, in order to reduce the noise of running is not widely spread on railway vehicles. The tests carried out by several Administrations (L.T.E., C.F.F., S.N.C.B., S.N.C.V., S.N.C.F., F.S.) have shown that from the point of view of noise, the advantages are very small, whereas it has often been found that vibrations are formed due to the apparently inevitable eccentricity of the elastic wheel under load. Rubber, in addition, heats owing to the braking and great frequency with which the stresses are reversed. Such wheels appear to be suitable above all in the case of small axle loads and moderate speeds. In this field, in fact, there have been several limited applications.

Experiments are still being carried out however by several Administrations, especially on account of the reduction in the stresses which it is hoped to obtain by the use of elastic wheels.

Wheels with pneumatic « Michelin » tyres are used on some French rakes and on the railcars of some colonial railways (Algeria, Indochina, Mozambique). From the point of view of noise, such wheels give good results, but their considerable and

well known restrictions from the point of view of axle loads, maintenance, track circuits, etc., lead us to consider them as still being in the experimental stage.

As regards the brake rigging, which is often the source of much noise, great care is now taken in its construction so as to avoid any play when new which will increase in service, by using pins and bushes of special steel, and fitting the faces in contact of sliding members with wood, rubber, leather, « ferodo », etc.

Some Administrations try to reduce the rigging to the minimum by using a brake cylinder on each bogie (N.S. and L.T.E. coaches) or each wheel (railcars of the S.N.C.F. and rail motor coaches of the F.S.).

Metal sheeting, another source of noise owing to its resonance, is always covered in up-to-date vehicles by anti-vibration materials, generally with a textile fibre, glass, or asbestos base, stuck on or packed in some way (such as « flock ») or else cork.

The squeaking of wooden panels is prevented by flannel or felt inserts below the beadings.

As regards the noise of the heat engines or electric motors, the greatest care is taken to balance them correctly, and in the case of the former, great care is taken in designing the exhaust.

As regards the gears, the tendency is to make them with a very accurate profile and to grind them. On railcars in particular, helicoidal gears are used in nearly every case. The L.T.E. reports in this connection that an appreciable reduction in the noise has been obtained by using an angle of  $7\frac{1}{2}^\circ$  for the teeth.

#### 2. Methods used to reduce the propagation of noise within the vehicle.

In order to reduce the propagation of noise due to the running through the suspension gear and metal structure, most Administrations make use of rubber inserts, or more rarely, felt, inserted where the body rests on the bogie, and sometimes between the springs and their supports.

However, recent trials made by the S. N. C. F. have shown that from the point of view of sound deadening the advantages of such inserts are very small. The said Administration is giving up using them on the vehicles now under construction.

On the contrary, as regards the propagation of noise and vibrations by the heat engines, the use of rubber inserts of the « silent-bloc » type, to fasten the engines themselves to the chassis is general.

For the insulation of the walls, floors and roofs, cork or materials with a textile fiber, glass or asbestos base are used, either in the form of a mattress or else sprayed on with a bituminous adhesive. There are several such materials, some of them the patented products of different firms. The thicknesses used vary between 8 and 30 mm (5/16" and 1 3/16"). The greatest thickness is used for floors and roofs. Some double or triple walls are used.

It has been found that imperfectly closed windows and doors greatly increase the level of noise. Some Administrations consequently take steps to make sure the doors and windows are really satisfactory. For these reasons there is a considerable reduction in noise in vehicles fitted with fixed double windows.

In railcars and rail motor coaches, the noise usually comes in through the holes made for the pipes, conduits, cables, etc., and inspection doors. Consequently such doors have to be carefully sealed with packings, and the inspection doors reduced to the minimum.

The heat engines are placed as a general rule in separate compartments, cut off from the rest of the vehicle by one or two well insulated partitions, sometimes of the « fire-proof » type, or else they are surrounded with an anti-noise bonnet. The exhaust is usually taken out above the roof.

### 3. Details of sound deadening inside vehicles.

The results of the measurements made by some Administrations cannot always be

compared, owing to the very different methods that were used.

It can be stated however that in well insulated up-to-date vehicles, both motor units and trailers, it is possible to obtain a noise level of the order of 70 to 75 decibels at speeds of 100 to 125 km/h. (62 to 89 miles). The noise is considerably increased when the doors and windows are opened.

An important reduction in the noise has been obtained by encasing the bogies, but the asbestos fittings used went constant deterioration in service.

### Lighting.

#### 1. Source and characteristics of electric current used for lighting.

24 V direct current is still the most widely used. There are however examples of different voltages being used on ordinary coaches: in Switzerland 36 V, Spain and Marocco 48 V, in Norway and America (P. E. N. N. A.) 32 V, etc. Still higher voltages (of the order of 72 to 120 V) are used by some Administrations, especially on railcars.

Alternating current is sometimes used, especially with fluorescent lighting. The voltages and frequencies used in this case a great deal, according to the application. There are examples of industrial frequencies being used (50 to 80 Hz, 110  $\div$  220  $\div$  380 V — S. N. C. F., F. S., S. A. R., P. E. N. N. A.) or high frequencies (400  $\div$  850 Hz, 110 V — N. S., L. T. E.).

Lead batteries are still the most widely used type, but the use of alcaline batteries (iron or nickel-cadmium) is beginning to develop.

The batteries are usually charged by generators on the vehicle. This is considered to be the most economical method, and that giving the greatest flexibility in operation. Only in the cases of the Algerian and Italian vehicles are fixed charging plants used. The F. S. moreover

are going over to charging the batteries on the vehicles.

The most widely used type of drive from the axles is the flat belt, or more rarely the V-belt. Today, however, drive by cardan shaft and gear box is being extended, especially in the case of the higher powers.

In the case of railcars, the generator is driven by the heat engine, generally by V-belt. In rail motor coaches the generator is most often driven by a motor supplied from the overhead line.

The power of the generators is of the order of  $1.5 \div 2.5$  kW for coaches without air conditioning or pulsated air heating, while it reaches  $20 \div 25$  kW on coaches equipped with air conditioning. In the case of railcars and rail motor coaches the power is necessarily higher, as the current generated is also used to feed the control circuit and to start the heat engines.

The voltage is generally regulated by regulators of the carbon column, comb, vibrator, variable metallic resistance types, etc., acting on the field of the generator itself. There are however examples of the Rosenberg dynamos (D. S. B.) and special exciters (F. S.).

In special cases (double or triple rakes, railcars or rail motor coaches with trailers, trains of regular composition) several Administrations use one or two generators to supply the whole rake. These generators are often run without any batteries. They are driven by an electric motor (Italian electro-trains, rail motor coaches of the F. S., S. N. C. F., S. N. C. V., etc., trains on the Swedish private railways, etc.) or by heat engine (rake on pneumatic tyres of the S. N. C. F.) or by steam turbine (suburban rake of the S. N. C. F.).

Generally some emergency lighting is provided, but not on every railway. This generally takes the form of candlestick and candles, or other similar means. With A.C. lighting, it is assured by a battery. Some Administrations (R. E. N. F. E., T. C., C. F. A., etc.) instal a coupling cable which

if necessary enables the lighting to be branched off the adjoining coach.

## 2. *Lighting installations.*

The most general type of lighting is undoubtedly that by incandescent lamps.

Fluorescent lamps are however being more and more extensively used. Most Administrations have both types in use, but are proposing to use fluorescent lighting on the vehicles now under construction.

The incandescent lamps are sited in the ceiling. In vehicles with side corridors, the power installed is on the average  $2 \div 3 \times 40$  W lamps or the equivalent per compartment, in first class,  $2 \times 40$  W in second class, and  $2 \times 25$  W in third class. Similar powers are installed in vehicles with centre corridors.

To prevent the light from the filament hurting the eyes, most Administrations use frosted or opaline bulbs or clear bulbs fitted in the ceiling with opaque or opaline shades.

The use of reading lamps, which can be switched on and off by the passengers, is widespread in main line coaches and their use is ever being extended.

In most compartment coaches, there is a switch by means of which the passengers can switch off the usual lighting and at the same time switch on the night light. In coaches with a centre corridor on the other hand, the switching on and off is usually done by the train staff.

Most Administrations protect the bulbs against shocks or theft by means of diffusers or simply cases, but use is also made of special caps and the bulbs are marked with the name of the railway company owning them.

The fluorescent lights are arranged in one or two continuous rows in the case of coaches with a centre corridor, longitudinally. In coaches with a side corridor, generally two groups of two tubes or two tubes per compartment are provided, arranged transversely.

### 3. Data concerning the lighting of vehicles.

Measurements of the intensity of the lighting at reading level have been made by several Administrations whilst the stock was running. The results varied considerably from one vehicle to another. In the case of new stock, nearly everywhere an intensity of 60 to 90 lux is stipulated in the case of 1st class, 45 to 60 in second class and 35 to 40 in third class.

The measurements made in vehicles equipped with fluorescent lighting have shown that it is possible with this method to get  $2.5 \div 3$  times greater intensities than with incandescent lighting, i.e. 250 lux and even more. Fluorescent lighting is therefore a real and incontestable element of comfort.

## Heating - Ventilation - Air conditioning - Heat insulation.

### 1. Steam heating.

One of the greatest difficulties met with in steam heating installations is to get the heating to work in a uniform fashion throughout all the coaches of very long trains. The measures adopted in general with this object in view are to raise the feed pressure in the main conduit and to use large pipes, which are well insulated.

In Italy, a pressure of 7 atm. is used, and in America (P. E. N. N. A.) it is up to 14 atm. In this case each coach is supplied from the main conduit by an inlet valve which reduces the pressure to  $1 \div 3$  atm. according to the type of vehicle.

In some countries, special methods are used, amongst which mention may be made of a special heating van at the end of the train (T. C.).

The S. N. C. F. make use of pulsated air heating, the air being heated by expanded steam. Naturally the same system is also used on coaches equipped with air conditioning. The other Administrations make use of radiators underneath the seats.

The corridor radiators are generally arranged along the body sides or interior

partitions. Certain Administrations (private Swedish Railways, Turkey, Portugal, etc.) heat the corridors either by means of pipes or radiators. Sometimes the main steam pipe itself is placed inside and acts as a radiator.

### 2. Electric heating.

For electric heating radiators are used in nearly every case. This method is considered to be the simplest and most efficient.

However some railways (S. N. C. F., N. S. B., N. S. private Swedish Railways) use pulsated air systems. It has been recognised that from the point of view of the comfort, this arrangement is extremely satisfactory; in particular, it does away with the disagreeable smell caused by the carbonisation of the dust accumulated on the radiators. Against these undoubted advantages, it has the drawback of a lower thermal output and needing more powerful accumulators to work it.

In effect, whereas in coaches heated by radiators the power installed for climates of the European type are from 25 to 35 kW per coach, in the case of coaches heated by pulsated air the power goes up to 45 kW.

The power required of the accumulators may be continuous as with heating by radiators, within limits of a few Watts (as in the Italian coaches where the switches are made so that no current is used until they are turned on); whereas with the pulsated air system, it may reach values as high as 950 W owing to the power consumed by the fans.

With heating by radiators, experience has shown that it is a good practice to provide air circulating ducts owing to the high temperatures of the heating elements.

In coaches with a side corridor, there is a tendency nowadays to adopt separate heating for each compartment, even in the international coaches where three different voltages are used (1 000, 1 500 and 3 000 V). In coaches with a centre corridor (including rail motor coaches) a single heating

circuit is generally used for the whole coach.

The corridor radiators are arranged as in the case of steam radiators along the body sides, so as to take up the least possible space. On the Italian coaches the corridors are heated by means of hot air heated by radiators placed in the compartments themselves.

Types of heating differing from the classic methods described above are also used. For example the mixed steam-electrical heating (N. S., S. N. C. B.) and footwarmers in woven material impregnated with plastic materials (B. R.).

The voltage for the heating installation is generally the same as that of the overhead line: 1 500 and 3 000 V in the case of D. C. and 1 000 and 600 V through a transformer in the case of A. C.

### 3. Heating by other methods.

Other methods of heating, neither steam nor electric, are used exclusively on railcars and their trailers, with the exception of a few special coaches equipped with a self-contained heating installation by thermo-siphon with a coal fired boiler.

The most widely used methods of heating for railcars are:

- heating by the exhaust gases circulating through radiators arranged at a low level;
- heating by hot air, circulated inside the vehicle, heated by the exhaust gases;
- heating by the engine cooling water, circulating through radiators in the passenger compartments;
- heating by hot air, circulating inside the vehicle, and heated by the engine cooling water by means of heat exchangers or small aerotherms distributed throughout the actual compartments.

The use of the exhaust gases gives very irregular heating; excessive when the engine is working under full load and

none at all on long down gradients. Direct heating by the engine cooling water means using very large radiators with a risk of freezing up in winter. The last mentioned system is satisfactory, but the heating power available is general insufficient for colder climates.

For the foregoing reasons many Administrations (B. R., P. E. N. N. A., S. N. C. B., D. S. B., N. S. B., C. F. R., private Swedish Railways, etc.) are tending to make use of coal or oil fired boilers to heat their railcars, sometimes in conjunction with the use of the engine cooling water.

The trailers used with railcars are always heated by boilers.

It should be noted that up-to-date oil fired boilers are entirely automatic: the lighting up and turning out of the burner are controlled by a thermostat sited in a compartment.

### 4. Regulating the heating.

In the case of steam heating, the passengers can usually regulate it by turning off one or all the radiators in the compartment.

On the other hand, in the case of electric heating, regulation is normally by means of thermostats acting on the relays of the heating contacts. In coaches with side corridors, the heating is generally regulated in each compartment separately, whereas in coaches with a centre corridor, including railcars and rail motor coaches, the heating throughout the coach is regulated at the same time.

With a mixed type of heating (steam-electric) the thermostat provided for the electric heating often also regulates the steam heating at the same time.

The thermostats regulate the temperature to within  $\pm 1 \div 2^\circ\text{C}$ . They are set as a rule for an average temperature of 18 to  $21^\circ\text{C}$ . Sometimes, it is possible for the passengers to adjust the regulating temperature, or turn the heating off completely, or have it on all the time.

In pulsated air installations, the temperature throughout the coach is usually regulated by a thermostat acting on an electric fan, or on an electric contact opening or closing the steam or electric heating circuit. Should the regulator fail to function, the temperature can be regulated by hand by the train staff. Certain Administrations provide adjustable steam valves for such an eventuality, and devices making it possible to alter the power of the electric radiators. Passengers on their side can control the admission of hot air into the compartments to some extent.

Some Administrations regulate the heating by varying the pressure in the steam conduit or the voltage of the electric heating, according to the outside temperature. In some cases such regulation is in addition to that by thermostat.

The regulation of the heating of railcars is also by thermostat, according to the system adopted acting either on the circulation of the air heated by the exhaust gases or the cooling water, or lighting and putting out the oil fired boiler. The train staff often regulates the heating manually, especially on the older types of railcars and those heated from a coal fired boiler.

The heating of the rail motor coaches is regulated in the same way as electrically heated coaches, i.e. either by thermostat or by the train staff, or both. Hand regulation in such cases is done by means of special devices which make it possible to alter the total power of the radiators or modify their position in the circuit, or alter the ratio between the length of the periods the electric circuit is completed and broken (F. S.).

It is noted that in railcars and rail motor coaches where the driver is always present, hand regulation by the train staff is more generally used than in the case of coaches, where automatic regulation predominates.

##### 5. Ventilation.

As a general rule the air inside the

vehicles is renewed by the opening of the windows and by means of special ventilators worked by the current of air produced by the running of the train. The latter, which can be of the suction or blower type, are sited in the ceiling or in the body sides under the windows.

There are however some cases of forced ventilation, especially on American built stock.

Obviously, vehicles equipped with air conditioning, which will be dealt with below, and those with pulsated air heating equipment also are provided with forced ventilation.

Forced ventilation generally renews the air at the rate of  $1500 \div 2500 \text{ m}^3$  per hour per coach.

##### 6. Air conditioning.

Air conditioning (also including the cooling equipment) is used above all in American (P. E. N. N. A.) and in hot climates (South Africa, Australia, India, Mozambique). In Europe, it is used on the fast Italian electro-trains, the Rumanian railcars, the British Royal Train, and in a few other isolated cases.

The cooling equipment (normally using freon; methyl chloride in Italy) generally has a power of 15 000 to 25 000 frig./h. per coach, according to the type of installation; the heating power varies considerably according to the climate (very few calories in Mozambique and none in India to 20 000  $\div$  30 000 cal./h. per coach in Europe and America). The renewal of air is at the rate of about 1 500 to 2 000  $\text{m}^3$  per hour per coach, whilst the total output (including recuperated air) reaches 4 000 to 5 000  $\text{m}^3$  per hour.

Installations making use of ice for cooling purposes are only used very exceptionally (British Royal Train).

The inside temperatures in the summer are maintained at about  $22 \div 25^\circ \text{C}.$ , with a relative humidity of 50 % approx., whilst during the winter the temperatures

are approximately the same as those provided with ordinary heating.

When there is a cooling installation, the windows are generally double and fixed.

The electric power required to work such installations is produced by dynamos driven off the axles, the power of which varies between 18 and 25 kW. Adequate batteries are provided to supply the necessary power whilst the train is standing. In the Italian electro-trains, the current is taken from the overhead line; on the Rumanian railcars, it is supplied by the heat engines.

#### 7. Thermal insulation.

The same materials are generally used for insulation against heat as against sound. Frequently several such materials are used in combination to attain the desired object. Sometimes layers of air are provided to complete the thermal insulation.

In very cold climates (Sweden, Norway, etc.) and where cooling installations are provided, fixed windows with double glazing are used. In some cases, passengers are protected against draughts by a second fixed glass in the lower portion of the windows (C. F. R., N. S.).

### Fittings.

#### 1. Seats.

In the first and second classes and in railcars and rail motor coaches used on luxury express services over long distances, upholstered seats are generally provided with head and arm rests. In 3rd class compartments, on the other hand, and in railcars and rail motor coaches used for stopping services, the seats have neither head-rests nor arm-rests and sometimes have low backs. There is a tendency to provide upholstered seats even in 3rd class, with head and arm-rests. This tendency is most noticeable in the countries where the journeys are the longest. Wooden seats are still widely used for services over short distances.

The most widely used method of upholstery is that using springs and hair. Sponge rubber and a mixture of rubber and hair (rubber-crin) are used by some Administrations (P. E. N. N. A., V. R., N. Z. R.).

Leather or imitation leather products are widely used to cover the seats. In Europe, however, velours and fabrics are still used on a large scale, especially in 1st and 2nd class.

Seats which can be turned into berths are being increasingly provided in countries where the journeys are long, or at least take a long time (S. N. C. F., C. F. A., C. F. I., N. S. B., C. G. R., S. A. R., T. C., Mozambique).

#### 2. Floor and wall coverings.

Plywood is often used to cover the walls, or a manufactured composition material of the « Masonite » type. Today a great variety of materials with a plastic base is also available, and these are used by many Administrations and have generally proved satisfactory. A few Administrations cover the walls with steel or aluminium sheet, painted or lacquered. Sometimes the walls are covered up to waist height by the same upholstery material as is used for the seats, or by pergamoid.

Linoleum is generally used on the floors. Sometimes rubber is used instead, or polyvinyl chloride (S. N. C. F.). In 1st class, the linoleum is often covered by a carpet or moquette. The P. E. N. N. A. used floors covered with asphalt tiles covered with carpets in the compartments.

#### 3. Arrangement of the compartments, seats, doors, etc.

In Europe the most usual arrangement is to have the seats facing each other, whilst in America, Africa and Australia, the seats generally all face the same way. The latter are often pivoting or have reversible backs, the slope of which can be adjusted.

In Europe, on main line stock, the

coaches are usually divided into compartments with a side corridor. Central corridors are nearly always used on coaches for local services and in railcars and rail motor coaches. In America, on the other hand, the centre corridor is the arrangement most widely used.

The number of seats across the compartment is generally 3 in 1st class, 3 or 4 in second class and 4 and sometimes even 5 in 3rd class. In railcars and rail motor coaches, there are nearly always 4 seats across, as also in most American vehicles.

The doors of the compartments are normally sliding doors. Those of the toilets, corridors, and outer doors are hinged doors. In railcars and rail motor coaches folding doors are sometimes used for the outer doors, worked by compressed air.

Small luggage can be carried in nearly every case in racks above the seats. On rail motor coaches and railcars however, there is generally a special compartment for luggage of large size.

From the information received it appears that special compartments are reserved for women with children by the Danish, Norwegian and Turkish Railways

only. Such compartments are specially arranged.

#### 4. *Arrangement of the toilets.*

The walls of the toilets are generally covered with painted, enamelled or vitrified sheets. There are also cases of rustless steel being used, plywood covered with plastic materials, etc.

The floors are made of mosaic, earthenware tiles, rubber with raised edges, asphalt, special cement, cast iron and concrete plates covered with a bronze grill.

Hygienic accessories (soap, towels, toilet paper, etc.) are provided in all cases, or are going to be provided after being stopped during the war.

The provision of hot water is beginning to become more extensive, at least during the times when the heating system is working.

### Stability of running.

#### 1. *Bogie vehicles.*

Bogies of the classic types are still used in nearly all cases under coaches by most of the Administrations, even in the case of new stock. These are summed up very briefly in the following table :

##### *Primary suspension (axle boxes).*

— coiled springs between the chassis and equalising bar . . . . .

— plate springs with coiled springs at the ends . . . . .

— coiled springs arranged beside the boxes . . . . .

##### *Secondary suspension (swing bolster).*

full elliptical plate springs.

do.

longitudinal plate springs with or without coiled springs at the ends.

{ nests of coiled springs.

full elliptical plate springs.

longitudinal plate springs with or without coiled springs at the ends.

If the suspension is well designed, such bogies give excellent results from the point of view of comfort, up to speeds of 110 to 120 km/h. (68 to 74 miles). One some

Railways (for example the P. E. N. N. A.) the classic bogies are used even at speeds of 160 km/h. (100 miles) and over. However such speeds with the classic types of

bogies presuppose specially well maintained stock and permanent way.

To obtain good running stability at such high speeds, even in the case of track maintained in the standard way, or to increase the comfort at the ordinary speeds, or to obtain other advantages (for example in connection with the price, weight, economies in maintenance, etc.), several Administrations have put into service or made trials of bogies differing more or less from the classic types.

Interesting examples in the case of trailer stock are :

- the bogies used on Swiss stock or stock of Swiss manufacture (S. W. S. type bogie) which, for the primary suspension, have coiled springs arranged at each side of the axle boxes with two special hydraulic shock absorbers inside which also act as the axle box guides, and for the secondary suspension, longitudinal plate springs, doubled by two additional plate springs which come into play after a certain load. These bogies have given very satisfactory results and have been extensively used;
- the bogies of the new Italian vehicles (type 27 bogie) the primary suspension of which consists of coiled springs at each side of the boxes which have rubber springs inside, working in parallel, and having a damping out effect. The secondary suspension of these bogies consists of plate spring with coiled springs above. The latter are also in parallel with the rubber springs, acting as shock absorbers. These bogies also have given good results and are used on all the new Italian stock;
- the bogies on the recent P. E. N. N. A. stock, which only differ from the classic « Pennsylvania » type by the reduction of the damping out of the secondary suspension, obtained by substituting for the classical full elliptical springs a combination of plate and coiled springs;
- the type I SIG and II SIG bogies used on some of the Swiss coaches, the primary and secondary suspensions of which are formed by springs with torsion bars. The first type has no bolster, this being replaced by the frame of the chassis itself which is suspended from the axle boxes by rods (links) fixed to the torsion bars, enabling it to oscillate laterally. The results obtained with this bogie are excellent for speeds of not more than 110 km/h. (68 miles), whilst at higher speeds it was found necessary to fit a hydraulic shock absorber on each torsion bar of the body suspension;
- the experimental type Y-20 bogies, put into service for trial purposes by the S. N. C. F., designed for speeds of 150 to 160 km/h. (93 to 100 miles), the leading characteristics of which are as follows : a) secondary suspension assured by coiled springs conjugates with the hydraulic shock absorbers; b) transversal suspension assured by the lateral flexibility of the coiled springs of the secondary suspension, this suspension being also controlled by the hydraulic shock absorbers; c) connections without any play between the different stages of the suspension, thanks to the use of rods with elastic joints, of the « silent-block type ».

In the case of railcars and rail motor coaches, either the classic types of bogies used with coaches are used, taking care in such cases to reinforce them and improve them, in order to avoid wear in service, or bogies of special types with special types of suspension.

The special characteristics of these latter bogies are usually dictated solely by the need to meet the constructional requirements due to the presence of the motor equipment, and to weight reduction. In such cases, the suspension is as a rule more

rigid and less comfortable than that used on coaches, and consequently of no interest as far as this report is concerned.

Other types of bogies used with railcars and rail motor coaches on the other hand are of interest from the point of view of comfort, as they tend to solve the problems mentioned above, without any sacrifice of comfort, and make it possible in some cases to obtain excellent running stability, even at the very high speeds at which such vehicles run.

In this field an interesting example is the bogie used under the new fast Italian electro-trains, the essential characteristics of which is the very high deflection of the springs combined with suitable damping out of the vertical oscillations. In the case of the primary suspension, this is obtained by means of coiled springs working in parallel with full elliptical plate springs, and in the case of the secondary suspension, by the use of plate springs divided up into groups of a few plates. The centering of the bolster is obtained by means of swing links used in conjunction with special rubber springs fitted inside the shock absorbers. These bogies run particularly well at speeds which may be as much as 150 to 160 km/h.

Bogies without swing bolsters are rarely used. Such designs are generally only used on rail motor coaches and railcars, being intended to simplify the construction of the bogies. The results are only satisfactory, or even bad. Though, when in new condition (flanges and axle guides without any wear), the stability of running is satisfactory, at least at speeds of not more than 90 + 100 km/h. (55 to 62 miles), as soon as there is any wear, vehicles without swing bolsters hunt rather badly, and these movements increase as the wear increases.

In some cases (F. S., V. R., S. G. C. E., etc.) similar devices are used, which have some advantages, by means of which the pivot is given a certain amount of transversal play, controlled by a centering device.

There is a general tendency, in the case of vehicles designed with the object of improving the comfort, to increase the elastic deflections of the springs, compared with similar previous constructions. In recent constructions they attain total values of 6 to 7 mm/t (15/64" to 9/32") on coaches and 8 to 9 mm/t (5/16" to 3/8") on light motor units; at least on those where factors affecting the comfort are considered by the designers to be of greater importance than other requirements (economy, simplicity, etc.).

Plate and coiled springs are the types still used on a large scale, generally in combination, with a tendency to increase the proportion of the latter. There are also some applications of torsion bars and rubber springs. The latter are used above all as auxiliary springs.

The steel used for the construction of springs is generally of the manganese-silicon type, water or oil hardened. The stresses allowed under the static load reach values of 50 to 60 kg/mm<sup>2</sup> (31.75 to 38.09 tons per sq. in.) for deflecting springs and 30 to 35 kg/mm<sup>2</sup> (19.05 to 22.22 tons per sq. in.) for torsion springs. Some Railways (F. S., C. F. E., V. R.) are beginning to use chrome-silicon steels, oil hardened only, with stresses of 80 to 90 and 45 to 50 kg/mm<sup>2</sup> (50.79 to 57.14 and 28.57 to 31.75 tons per sq. in.) respectively.

The rubber components are stressed up to 20 + 30 kg/cm<sup>2</sup> (284 to 428 lbs. per sq. in.), whereas in the case of the actual rubber springs a stress of 10 kg/cm<sup>2</sup> (compression) is not usually exceeded.

In the case of vehicles designed for speeds of not more than 100 km/h. steps were practically never taken in the past to control the damping out of the oscillations either vertical or horizontal.

Today, on the contrary, on many up-to-date vehicles intended for high speeds, there seems to be a definite tendency on the part of the designers to control such dampings out as much as possible. The vertical suspension is damped out at times

by using coiled springs coupled to hydraulic shock absorbers, but most frequently a judicious combination of coiled springs and rubber or plate springs is used, the latter being divided up into groups of a few plates. Applications of this type have been mentioned above.

To damp out the lateral oscillations of the bolster, it is becoming a wide spread practice to use hydraulic shock absorbers.

There is a tendency for some Administrations to reduce the centering effect of the swing bolsters by increasing the length of the swing links (which are sometimes made  $400 \pm 500$  mm), increasing thereby the amount of displacement allowed (up to 40 to 50 mm). In some cases the swing links are replaced or completed by a spring centering device (Y 20 bogie of the S. N. C. F., fast Italian electro-train, etc.).

As regards the support of the body on the swing bolsters, use is made of the two systems of a central carrying centre-plate with side bearers with a slight clearance and the whole application of the weight on to the side bearers. The first system, which gives the bogie great freedom of movement, is usually preferred on railways where there are a lot of curves. The second system makes it possible to lighten the bolster and prevents any play. In order to enjoy the advantages of both systems, in some cases a compromise between the two has been adopted; the body rests on the swing bolster by a central centre-plate and two elastic side bearers whose elasticity is so calculated that there is a predetermined distribution of the load between the centre plate and the bearers (Y 20 bogie of the S. N. C. F., F. S. rail motor coaches, etc.).

In high speed vehicles there is a tendency to reduce the play in the axle box guides, keeping them within 1 or 2 mm ( $3/64$ " or  $5/64$ ") by using special materials for the guides (manganese steel against manganese steel or manganese steel against materials with a phenoplastic or asbestos base). There is also a tendency in some

cases to guide the boxes and bolsters by means of small articulated rods or arms, sometimes with rubber joints.

The light types of vehicles often suffer from vibrations of the body which are felt particularly in the central zone of the main girder of the frame. These vibrations, due to the decrease in rigidity owing to the light weight construction, can be reduced in the opinion of some Administrations (S. N. C. F., C. F. F., F. S., etc.) by increasing the deflection of the suspension and reducing to the greatest possible extent the friction of the springs, especially in the secondary suspension. Naturally research into the rational distribution of the material in the construction of a body, giving it the maximum rigidity for a given weight, will also tend to reduce such vibrations.

Finally in order to improve the stability when running at high speed, several Administrations have made trials of tyres with a profile of 1/40 and even 1/100 (B. R.). It has generally been found that this led to an appreciable decrease in hunting; on the other hand the wear of the flanges is much more rapid. All the coaches of the C. F. F. and all the railcars of the S. N. C. F. and D. S. B. are fitted with tyres with a profile of 1/40.

## 2. Four and six wheeled vehicles.

There have been no noteworthy innovations in the case of four and six wheeled railcars. Such vehicles are usually intended for moderate speeds, where there is no particular problem as regards the comfort.

Devices intended to improve the stability of such vehicles have however been tested, based on the principle of allowing the axles to take up a radial position (F. S.), and connecting to the ends of the chassis the ends of the plate springs of the axle boxes by means of rubber components, thus doing away with all longitudinal and transversal play (S. N. C. F.).

## 3. Measuring the stability.

Measurement of the running stability of

vehicles by means of recording apparatus has been carried out on several Administrations. Such measurements give useful information for comparing various designs tested to enable the results obtained to be estimated. In most cases however, the measurements only have a relative character, and have no absolute value, to enable a direct estimation of the degree of comfort of a vehicle to be made.

### Summaries.

#### A) SOUND INSULATION.

1) The experiments carried out by different railways prove that elastic wheels do not lead to any appreciable improvements from the point of view of the sound insulation of vehicles. Such types of wheels can even be the source of parasitic vibrations in themselves.

2) It is possible to reduce the formation of noise by :

- simplifying the brake rigging and doing away with a central rigging;
- providing suitable guides for all the moveable parts of the body;
- covering the body sheets with absorbant substances and reducing the size (area) of sheets used;
- using helicoidal gears in the drive of railcars and ground gears for rail motor coaches.

3) The use of anti-vibration packings between body and bogie is very widespread. The S. N. C. F. doubt their utility however.

4) The suspension of the heat engines is always completed by very elastic rubber packings.

5) In the construction of up-to-date rolling stock, extensive use is made of absorbant substances on the walls, floors, ceilings and doors.

Such substances provide satisfactory heat insulation. The latter is completed, in very cold countries, by the use of double windows.

6) There is a tendency to equip railcars with a platform or luggage compartment between the compartments and the driving compartment.

7) The transmission of noise can be reduced by carefully packing the trap-doors in the floors and the holes for the pipes and conduits.

#### B) LIGHTING.

1) Up to the present incandescent lamps have been widely used. Fluorescent lighting is now developing very rapidly.

2) At the present time the filaments of incandescent lamps are screened by using either opaque bulbs or opaline diffusers.

3) For some years there has been an appreciable increase in the amount of light provided (90 lux in 1st and 2nd class; 50 lux in 3rd class at reading level). With equal power installed, the lighting can be tripled approximately by the use of fluorescent tubes.

#### C) HEATING — AIR CONDITIONING — VENTILATION — HEAT INSULATION.

1) With steam heating, there is a general tendency to increase the feed pressure in the main steam pipe in order to improve the heating of the last few vehicles of the train.

2) In the corridors of compartment coaches, the steam or electric radiators are arranged either against the body sides or against the compartment partitions, or in the compartments themselves. Some railways use the actual steam conduit as a radiator for heating the corridors.

3) Direct electric heating by radiators is the most widely used and most economical method. It gives satisfactory results provided the circulation of air around the heating elements is adequate.

4) Pulsated air electric heating increases the comfort, and also makes it possible to

ventilate the vehicles during the summer. However, the consumption of current in high and low tension is much higher than with direct heating.

5) The compartments are generally heated individually, with thermostatic control.

6) In railcars, heating by the engine cooling water or exhaust gases does not usually give sufficient comfort. On both vehicles and trailers the present tendency is towards the use of coal or oil systems of heating. In the latter case, the working can easily be made automatic.

7) Coaches not equipped with air conditioning or pulsated air heating are nearly always equipped with ventilators in the ceilings or walls. A few applications of forced ventilation have also been carried out.

8) Air conditioning is in general use in the U.S.A. and in tropical countries. In Europe, it has only been tried to a very limited extent.

9) In coaches equipped with air conditioning with cooling equipment, use is always made of double fixed windows.

#### D) FITTINGS.

1) In coaches of European construction, the seats always face each other, whilst in America, Australia and Africa they often face in the same direction, and can generally be reversed and have adjustable backs.

2) In Europe, springs and hair are used to upholster the seats. In America, Australia and Africa, sponge rubber is also used.

3) The use of leather or similar synthetic products has been greatly extended for seat coverings, except in cold countries and in Europe, where textile materials are still widely used.

4) Head and elbow rests are still used in 1st and 2nd classes.

5) There is a definite tendency to pro-

vide upholstered seats in 3rd class, as well as seats that can be turned into berths on coaches making long runs.

6) The centre corridor is almost general practice in the case of stopping train coaches, and also for railcars and rail motor coaches.

7) In Europe the main line stock often has a side corridor, whilst in America, the centre corridor is the most common.

8) In Europe, there are 3 seats a side in 1st class, 4 and sometimes 5 in 3rd class. There are 3 or 4 seats a side in 2nd class.

9) On railcars and rail motor coaches, and on all the American coaches, there are 4 seats a side.

10) Plywood or composition material (Masonite) is widely used to cover the walls. Special coverings of plastic materials are also being used.

11) The floors are generally covered with linoleum, and more rarely rubber. These materials are sometimes covered by a carpet in 1st class.

12) The walls of W.C.s are covered with painted, enamelled or vitrified sheets. There are also some examples of rustless steel being used, or plywood covered with plastic materials.

13) The floors of W.C.s are in mosaic or earthenware tiles, in rubber with coverings, special asphalt or cement, or metal grills.

14) Hot water for washbasins in the W.C.s is beginning to be provided more generally, especially during the winter.

#### E) STABILITY OF RUNNING.

1) Most Administrations continue to use the classic types of bogies on their up-to-date stock as previously standardised.

2) Such bogies can be used at high speeds provided special care is taken in the maintenance of the stock and permanent way.

3) Bogies of special types for ordinary and high speeds have recently been tried and seem likely to be generally used on the future rolling stock of some railways. However, in the design of bogies other factors than the comfort must also be taken into account (cost, weight, ease of maintenance).

4) The use of bogies without swing bolsters has been very limited to date, and is not likely to be made general.

5) An increase in the flexibility of the springs is likely to improve the comfort. It may also be necessary on account of the lightening of rolling stock, plate springs, coiled springs or a combination of the two types remaining current practice. The use of coiled springs is extending compared with that of plate springs.

6) The use of torsion bars is not very extensive. Rubber is used more and more for auxiliary springs but not often for the main springs.

7) Some railways check the damping out of the vertical and horizontal oscillations, either by combining different types of springs or by hydraulic shock absorbers.

8) For high speed rolling stock, there is a general tendency to reduce the play in the axle box guides, either by using special materials, or by special designs of guides without play.

9) According to certain railways, the reduction of the coning of tyres makes it possible to improve the comfort by reducing hunting. This measure however results in increased wear of the flanges.

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### QUESTION V.

## Improvements in the construction of rolling stock (motor and trailer) in view of increasing the mileage between repairs :

- solid wheels or with tyres (metal used for the tyres and solid wheels, behaviour in service);
- axle boxes;
- wearing and friction metals;
- springs (qualities, shape, manufacture),

by Georges CHAN,

Special Reporter.

Question V was dealt with in the three following reports :

Report (America (North and South), Burma, China, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan), by Messrs E. PUGSON and L. LYNES (See *Bulletin* for April 1950, p. 683);

Report (Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Portugal and Colonies, Rumania, Spain, Sweden, Turkey, Yugoslavia), by Messrs A. d'ARBELA and M. FASOLI (See *Bulletin* for July 1950, p. 1449); and

Report (Belgium and Colony, Denmark, France and French Union, Luxemburg, Norway, Netherlands and Colonies, Poland, Switzerland and Syria), by Mr. G. CHAN (See *Bulletin* for August 1950, p. 1755).

As the capital cost of Modern Rolling Stock is high every endeavour is made to reduce the time out of traffic by using it intensively and by interrupting its service at as long intervals as possible and for the shortest time. Amongst the parts requiring most attention and maintenance are, as would be expected, the running gear, wheels, axle boxes, guides and springs, details common to all rolling stock.

Question V has, as object, the improvements recently introduced to these parts in

order to ensure they remain longer in good order in service and to obtain a greater mileage between withdrawals for repairs.

Before summarising the replies mentioned in the above reports and attempting to draw up the summaries thereof, the order of the questionnaire will be followed and the information relating to the various kinds of rolling stock collected together. The very object of Question V enables us to collect together without any disadvantage the data relating to steam electric and Diesel locomotives, electric railcars, and rail motor coaches, and to carriages and wagons, whilst mentioning, should the need arise, certain particular aspects of some other rolling stock.

The order of the questionnaire leads us to show first of all the extent of the progress effectively realised and then to analyse the methods used; we have endeavoured in particular to draw attention to the use made of the general progress in industrial technique and notably in the use of special materials such as india rubber, plastics, compressed powder (frittage), etc.

#### General.

(Questions 1 to 3.)

The Administrations agree that periodic

repairs to the frame and running gear are determined by tyre wear. Some Railways (Netherlands and Norway), however, report the wear of axle boxes and mechanism as equally responsible. Treads of tyres of locomotives are allowed to wear hollow to the extent of 5 mm (13/64"). In the case of rolling stock the figures given by British Railways may be noted: 1.6 mm (9/128") for high speed carriages, 2.4 mm (3/32") for other carriages, and 4.8 mm (3/16") for wagons. Details will not be given of the mileage between repairs for lifting which vary according to the stock and the conditions of working, but details of the progress made will be mentioned. Thanks to the whole of the improvements effected in the running gear and in the layout of the frames, there is a definite tendency towards increased mileage between lifting. For example the S. N. C. F. report that in the case of its recent 282-R locomotives the mileage has risen from 70 000 km (43 000 miles) to 120 000 km (74 000 miles) and even to 140 000 km (86 000 miles) when fitted with all improvements (very rigid monobloc frame, roller bearings, axle boxes, automatic (self adjusting) axle box wedges). The Netherlands Railways report mileage of 160 000 km (100 000 miles) as against 100 000 km (62 000 miles) previously. The British Railways (L.M.R.) give an example in which by using manganese steel wear plates on the axle box guides, the mileage has risen from 105 000 km (65 000 miles) to 160 000 km (100 000 miles).

In the case of electric locomotives, one important advantage relatively to the steam locomotives is that the pairs of wheels can wear differently one to the other and can be changed over if desired. The Italian State Railways state that with their electric locomotives they are exceeding 200 000 km (124 000 miles) as compared with 130 000 km (80 000 miles) with their best steam locomotives. Then too the recent electric locomotives are better than the earlier ones. For example the BB 8100 of the S. N. C. F. run 220 000 km (136 000 miles) a gain of 10 % and the Norwegian locomotive

200 000 km (124 000 miles) instead of 120 000 km (74 000 miles). As regards carriages the New Zealand's carriages on roller bearings are lifted at 160 000 km as compared with 135 000 km (83 000 miles) for the other stock. The recent C. F. F. carriages of light construction with solid wheels, roller bearings and the new S. W. S. bogies, run between two consecutive repairs, i.e. during one year, 3 to 4 times the mileage of the other vehicles.

Although the reduction in maintenance costs of modern stock is very notable for equal service, the railways usually order new stock for other reasons, such as for example, to increase the adhesion, the power, the comfort and the speed or to get operating economies. The Administrations feel that when placing orders, they will make a substantial profit by introducing improvements designed to increase the mileages.

### One piece wheels.

(Questions 4 to 14.)

Ignoring one piece cast iron wheels the drawbacks of which are well known, the information on one piece rolled or cast steel wheels is summarised below.

The use of these wheels has the advantage of obviating slack tyres in service, a feature of special value for certain passenger trains, and for trains having to be braked down long grades. Another advantage is that as the rim does not have to withstand the tension of the tyre they can be lighter which explains their use on carriages, electric motor coaches, and rail cars which are lightened stock for rapid acceleration.

One piece wheels are in general use in the U. S. A. on all new rolling stock other than the driving axles of locomotives, on which their use is said to be uneconomical. The other Administrations report a considerable use (the British Railways, on carriages and wagons (L. M. R.); South African, also on carriages and wagons; C. F. F., electric motor coaches and carri-

ages; Spanish, on carriages; S. N. C. F., on tenders, locomotive carrying axles, motor coaches and rail cars).

Apart from cases when the one piece wheel is preferred for weighty reasons, to avoid all risk of tyre movement, as for example on passenger carriages on long international services, the choice between the one piece and the tyred wheel is governed by the cost, which depends upon the service life and the wear resisting qualities of the one piece wheel.

In this connection the use of wheels with the treads *hardened by heat treatment* has been reported and examples will be given later.

The Class 'C' wheel used on the Pennsylvania Railroad is made of 0.67-0.77 % carbon steel quenched and tempered to give the tread a hardness of 107 to 120 kg/mm<sup>2</sup> (67.93 to 76.19 t per sq. in.).

The London Transport Executive use, for its carrying wheels, a 0.5-0.6 % carbon steel hardened by quenching the tread. The British Railways' wheels are not specially air-hardened and are made of class 'C' steel giving 79 to 86 kg/mm<sup>2</sup> (50.16 to 54.6 t per sq. in.).

After many tests, the C. F. F. have adopted rolled wheels of ordinary carbon steel giving 70 to 85 kg/mm<sup>2</sup> (44.4 to 53.97 t per sq. in.) in the annealed condition and raised to 100 to 110 kg/mm<sup>2</sup> (63.49 to 69.84 t. per sq. in.) by quenching in an oil bath the wheel after having raised the temperature of the tread to a higher temperature. The depth of the wear layer is 35 to 40 mm (1 3/8" to 1 37/64"). Satisfactory results have also been obtained by the C. F. F. with cast steel wheels quenched not by complete immersion but by jets of water projected on the tread.

This last process, by local spraying, is also used by the S. N. C. F. on wheels now being made of 80 kg/mm<sup>2</sup> (50.79 t. per sq. in.) steel hardened to 100 kg/mm<sup>2</sup>.

The manufactured wheels just mentioned are all made of *ordinary carbon steel*. Tests were made in 1938 of special chrome

*molybdenum steel* wheels treated on the 30 mm (1 3/16") thick rim to 110 kg/mm<sup>2</sup>. These wheels were used on the S. N. C. F. electric motor coaches but at the beginning of the experiment the treads flaked or scaled whilst the thicker 60 mm (2 23/64") rimmed ordinary steel wheels gave satisfactory results.

The general tendency is to use ordinary carbon steel of the same quality as that of the tyres.

It is interesting to note that the surface of the one piece wheel can be hardened better than that of tyred wheels as there is no initial tension in the metal as with a shrunk on tyre. This is so much the case that we can get a one piece wheel of ordinary steel treated to give 100 kg/mm<sup>2</sup> whereas special steel would have to be used to get this hardness with a tyred wheel as we shall see hereafter.

*What is the comparative cost of the one piece wheel and the tyred wheel?*

With regard to the purchase cost, the British, Indian and New Zealand Railways report that the first cost is lower in the case of the solid wheel and the total cost may be advantageous if the centre is tyred when worn down. The L. M. R. is making experiments to obtain precise information on this matter.

The London Transport Executive after 30 years experience report there is practically no difference between the total cost of the two types and that it has adopted the one piece wheel for all carrying axles. The Victorian Railways (Australia) have given a figured comparison between the one piece wheel taken as being tyred when worn down to the minimum and ordinary tyred wheels; which has lead them to prefer the latter.

The C. F. F. (Switzerland), without giving any detailed indication as to costs, estimate that all things taken into account the expenditure is lower with one piece wheel.

The differences in the opinions given, it

would appear, are due to the different operating conditions (for example the frequency or duration of brake applications).

The Administrations favouring the one piece wheel are, it would seem, especially those using wheels with treads hardened by heat treatment.

The conclusion to be drawn appears to be that the one piece wheel can be used with advantage under certain conditions and that the experiments begun several years ago ought to be continued. A wider use, moreover, is likely to reduce the first cost by manufacturing in greater quantities.

The questionnaire raised the question of *building up* wheels by added metal. This process is generally proscribed because of the hardness of the steel. The C. F. F. however have built up flanges by electric welding. The Oxelösund-Flen-Västmanland Railway usually carries out such building up but uses in connection therewith wheels of relatively mild steel (type 44 steel with 0.2 % carbon for wagons or type 55 for railcars).

No particular *speed limit* is reported in connection with the use of one piece wheels.

As regards *surface defects* no difference is found as a rule between the two types, the one piece wheel and the tyred wheel, flaking or scaling being no more frequent with one or other type. However, the Southern Region of the British Railways considers that it is essential to use only *cast iron brake blocks* with one piece wheels. This Administration has found that non-metallic brake blocks used on electric rail motor coaches with frequent high pressure brake applications resulted in the development of cracks radially to the surface. No other Administration has reported any similar experience but then cast iron blocks only are generally used.

### Tyred wheels.

(Questions 15 to 21.)

From the numerous examples given, we

can say that *increasing the hardness of tyres* diminishes the wear in service. The S. N. C. F. quotes the case of their 282-R locomotives with  $90 \text{ kg/mm}^2$  (57.14 t. per sq. in.) instead of  $80 \text{ kg/mm}^2$  (50.79 t. per sq. in.) and the 2D2 electric locomotives in which the use of Bedel BNAV2 chrome molybdenum steel heat treated to give  $110 \text{ kg/mm}^2$  (69.84 t. per sq. in.) has increased the mileage between shopping of the carrying axles from 164 000 km (102 000 miles) to over 372 000 km (235 000 miles).

The tyres vary in hardness from one Administration to another from  $75 \text{ kg/mm}^2$  to  $108 \text{ kg/mm}^2$ . Most frequently the hardness is  $75\text{--}85 \text{ kg/mm}^2$  (47.62 to 53.97 t. per sq. in.) (Denmark, France, Italy, Switzerland); it increases to 80 to  $90 \text{ kg/mm}^2$  (50.79 to 57.14 t. per sq. in.) in other countries (Belgium, Holland, Norway) and to still higher values in certain countries notably in Great Britain where locomotive tyres are heat treated to give 88 to  $97 \text{ kg/mm}^2$  (55.87 to 61.58 t. per sq. in.) and even to 99 to  $108 \text{ kg/mm}^2$  (62.85 to 68.56 t. per sq. in.).

From the figures given in the reports the conclusion can be reached that ordinary annealed steel tyres can be used with a hardness of  $85 \text{ kg/mm}^2$  and even close to  $90 \text{ kg/mm}^2$ . Starting from  $90 \text{ kg/mm}^2$  and over, the steel has to be heat treated. Providing steel of certain qualities be used, and examples are given in the British Railways Specifications, we can envisage the use of carbon steel tyres oil hardened to give 88 to  $97 \text{ kg/mm}^2$  or chrome molybdenum steel tyres heat treated to give 99 to  $108 \text{ kg/mm}^2$ . These indications are valuable seeing as we said above increasing the hardness of the tyres is one method of increasing the mileage between repairs.

As regards the usefulness of giving special attention to the *machining of the surfaces of the wheel centre and tyre in contact*, to eliminate movement of the tyres some Administrations report that they are satisfied with rough surfaces not smoothed finished, but taking the railways on a

whole, the opinion is that the surfaces should be very carefully finished.

The tyres are *shrunk on* with allowances which vary greatly as between railways. The Pennsylvania R. R., which uses tyres on the driving wheel of its locomotives, has adopted a value of 1 to 1.3 per thousand. The British Railways use a lesser shrinkage varying from 0.8 per thousand on the L. M. R. to 1.2 on the L. N. E. R., whereas on the S. N. C. F. and the Italian State Railways, we find a shrinkage of 1.3 and even 1.5 per thousand. It is difficult to come to any conclusion as to the optimum value of shrinkage allowances, as the value depends upon the degree of finish of the machined surfaces, of the strength of the wheel centre, etc. An average value 1 to 1.2 per thousand appears to represent general practice.

*Building up by welding* is used sometimes to repair flanges (C. F. F. electric locomotives) but rarely the treads. As regards the latter we have only noted its use on the Luxemburg, Moroccan and Turkish Railways. The tyres are never fastened to the rim by welding. Trials were made on the C. F. F. some fifteen years ago but cracks developed in the welding.

#### *Flange or rail lubrication:*

The wear of rails and flanges is much reduced by lubricating these details.

This lubrication used to a considerable extent in Italy and Switzerland with their mountain lines with sharp curves and also in other countries of the Continent (Belgium, Spain, France) gives valuable results. The C. F. F. quote the case of mileages between repairs that have trebled (in the case of Ee 3/3 locomotives the mileage has risen from 16 000 to 50 000 km) and the case of the Brünig motor coaches when this lubrication by itself increased the mileage from 6 000 to 20 000 km. In France, it is estimated that on lines with curves of less than 500 m (1 640 ft.) radius by lubricating the rails and flanges the life

of the rails is doubled and that of the flanges lengthened by 60 %.

The devices used vary widely. Some railways fit the equipment on the track but generally where it is a question of lubricating the track over some distance the preference is given to installing the fittings on the locomotive to lubricate either the flange or the rail. Lubricating the flange is more the general arrangement, and this varies from a simple pad applied to the flange to more complicated equipment. Rail lubrication by the locomotive does not appear to be extensive except in France where its use is claimed to reduce the consumption of oil. In addition, to lubricating by oil, colloidal graphite is used on Belgian electric locomotives, exhaust steam (Luxemburg) and even water a process tested on some Netherlands Railways shunting engines and also in South Africa, where however it has been given up owing to the cost of maintenance.

The Cairo Congress of 1934 had noted the importance of lubricating rails and flanges and recommended the development of a practical lubricator. From the information received, it appears that there are many appliances which give valuable results without it being possible to say anyone type of appliance has imposed its adoption.

#### *Influence of hunting on tyre wear:*

Some Administrations have given valuable information on the effect of hunting on tyre wear. The South African Railways mention that the problem arose in connection with its BB electric locomotives, and it was found essential to brake the rotation of the bogie round the pivots to reduce the wear. In the same order of ideas, the C. F. F. report that the elastic transverse couplings of the two bogies of a locomotive or rail motor coach has made it possible to raise the mileage on the Brünig line from 20 000 to 100 000 km (fig. 24, page 593/55 of the *Bulletin* No. 8 of August 1950).

The Italian State Railways recognise the

influence of damping the hunting action on tyre wear, but point out that the object of this damping is usually to improve stability rather than to reduce tyre wear.

Later, in connection with Question 40, attention will be called to different devices introduced recently to reduce play between bogie wheels and frames in the direction of the track and to diminish the hunting movement. The results reported by the S. N. C. F. in connection with its BB 8100 electric locomotives with boxes guided by rods mention that the mileage of tyres is increased.

### **Independent wheels.**

(Question 22.)

Independent wheels are those which placed in line transversely to the track can revolve independently of one another like the carrying wheels of an automobile. Tests were made in Italy to try the effect of such wheels on the running conditions. Wear of the tyres at cross corners of the bogie was noted and the test was stopped. The British Railways (L. M. R.) also found as a result of a trial under a carriage that the wear increased, and the C. F. F. in a test on a special bogie reached the same conclusion, the tyres wearing irregularly.

The only satisfactory results, i.e. without abnormal wear, are in the case of wheels in the middle of 6 or 8 wheeled bogies with the outer wheels of the usual type (S. N. C. F. Bugatti railcars, and New Zealand Vulcan railcars). The Turkish State Railways use independent wheels but have given no information as to wear.

The above results appear to allow us to say that independent wheels have little chance of success and certainly so when used as guiding wheels. In any case, it does not seem likely to provide a contribution of any value to the problem of reducing the wear of details, the object of question V.

### **Roller bearing axle boxes.**

(Questions 23 to 29.)

Roller bearing axle boxes, which have

been used on carriages for a long time, have been fitted to steam locomotive driving wheels as well as carrying wheels (S. N. C. B., S. N. C. F., Netherlands, Victorian, British Railways (L. M. R.), and in a general way in the U. S. A.). These boxes are also used in electric locomotives (C. F. F. notably) and as general practice on railcars.

As we have already said their use on carriages is already old.

As regards wagons, the Netherlands Railways have fitted all new wagons since 1945. In the U. S. A., the Pennsylvania R. R. points out that oil boxes are fitted on all carriages and are now being extended to the wagons.

The advantages reported from using roller bearing boxes are first and foremost the rarity or complete absence of heated bearings and the reduced costs of maintenance.

In the case of steam locomotives, interesting information has been supplied about the results obtained on the S. N. C. F. on one large class of steam locomotives of the 282-R type, of which 700 have ordinary boxes, and 623 roller bearing boxes on the driving wheels or on all the coupled wheels. This Railway considers the application to the driving wheels alone is an effective improvement.

The Netherlands Railways whilst mentioning the great mileage of the 460 type 4000 locomotives have not come to any conclusion on the matter. On carriages the Administrations agree that cases of hot-boxes are very rare. For example, the C. F. F. has only some 10 on their 300 bogie carriages put into service since 1937 and not a single case on the motor coaches since 1935.

Greasing is done at widely spaced intervals, the lubricant is filled up monthly, the grease is replaced on lifting (between 100 000 and 200 000 km alone), and the box taken down after running about 500 000 km.

On the Victorian and Portuguese Rail-

ways, the mileage before replacement reaches 2 000 000 km.

Some *defects* are reported : corrosion ascribed to steam and water getting into the bearings (Netherlands Railways steam locomotives) broken journals in line with the end of the conical sleeve locating the roller race in certain boxes (carrying axles of S. N. C. F. electric locomotives and rail-cars). These defects have been or are being eliminated. It has been desirable to well round-off the edges of the locking details. On the other hand, the cracks in the journals seem to be tied to inadequate journal diameter. The values adopted will be found in the table of the Reports.

Some information on *maintenance costs* of the two types of boxes have been given. The Netherlands Railways give the maintenance costs as 27.2 florins per annum for a type R.2 box with brasses and 12 florins for a R.9 box with roller bearings. The London Transport Executive state the annual repair costs per annum are £ 4.24 per roller box and £ 36.9 per ordinary box with brasses.

The *types of boxes* used are the S. K. F. barrel roller type, on the *Timken* tapered roller or the cylindrical roller type (RIV of the Italian State Railways, Hoffman of the London Passenger Transport, Hyatt of the American Railways).

The *protection of the rollers* from the entry of dust and water, after many attempts by using felt and a labyrinth, is now sufficiently covered by a labyrinth alone.

To secure the *roller bearing in place* in the journal, two systems are in use :

- the bearing is pressed on to the journal, in a press giving a direct fit (*Timken*, RIV, Hyatt, Hoffmann);
- the bearing is held in place indirectly by means of a tapered sleeve which can be taken off (S. K. F.).

In the first system, the bearing is properly secured in place, but when it is necessary to take it off, as for examination of the journal, the latter can be damaged.

In the second, there is no difficulty in taking the bearing off. The disadvantage is that if badly fitted the inner ring can turn.

Some Railways (the Pennsylvania, British [L. M. R.]) prefer the press fitting. In spite of the readiness with which the tapered sleeve can be taken down, the South African Railways agree with this opinion whilst stressing that if the fitting pressure is insufficient the taper sleeves can turn and damage the journal, and that if the pressure is excessive this may explain cracks in the journal.

It must be noted that most of the other railways have expressed no preference and use both these methods together.

Railways using roller bearings on electric locomotives and motor coaches *fit a device to ensure the return current does not pass through the bearings and so cause pitting.*

Usually, carbon brushes rubbing on a disc or collector secured to the axle to the quill are fitted. The Italian State Railways as a result of their experience consider that when it is possible to establish a direct connection between the body of the vehicle and the wheels through plain bearings (bearings of nose suspended motors or the brasses of the quills) there is no reason to fear damage to the races of the axle boxes even in the absence of the brushes.

### **Boxes with plain bearings.**

(Questions 30 to 35.)

The boxes with oil circulating through them of the Isothermos type (Athermos with plain bearing) are very widely used on carriages and also on electric locomotives and tenders. The Friedmann-Stemi also an oil circulating type is used on tenders (S. N. C. F.). These boxes are described in the reports.

Amongst modifications made recently to the classic box with brasses it is interesting to mention the appearance (or reappearance) of steam locomotive boxes with the brasses completely enveloping the journal, by using two half brasses with a vertical

joint bolted together like a big end bearing. The lubrication is by mechanical lubricator without the usual under lubricating pad. This system is used on the S. N. C. F. (fig. 8, page 568 of the *Bulletin*, August 1950) and on the Southern Region in England (fig. 15, page 738 of the *Bulletin*, April, 1950) and has given good results. On the S. N. C. F. express locomotive of the 462 SUD-EST type the mileage between repairs to such axle boxes has been more than doubled.

Amongst improvements to *lubrication pads* are better quality wool and wicks in one piece between the oil well and the journal face of the pad.

The *antifriction* metal used on locomotive boxes is always of high tin content (78 to 85 %). The European Railways which in the case of carriages were obliged to use lead base metal (85 % lead) during the war, continue to use it. There is a tendency on the Continent to return to the rich tin alloy at least on express stock. (The Italian State Railways report the tin content has been raised, the C. F. F. and Norwegian Railways use a 80/83 % tin alloy and the S. N. C. F. intend to return to their 78 % tin metal.) The British Railways continue to use a 60 % tin metal.

The Italian Railways report having developed for their wagons a bearing consisting of a steel shell with antifriction lining in rose metal (Cu = 69, Pb = 30, Zn = 1) moulded separately, and pressed into place. It is being used on a large scale. The liner is also made by sintering and is an interesting example of powder metallurgy as a very homogeneous alloy can be obtained in this way, very important in this case, as homogeneous lead copper alloys are difficult to obtain by the ordinary fusion method.

The use of thin layers of antifriction metal has been practised for some years. The British Railways use a thickness of 3 mm (1/8"). There is a tendency to return to thicker layers. As an example, the Italian State Railways use 7 to 8 mm

(9/32" to 5/16") when the bearing is new with a minimum in service of 4 to 5 mm (5/32" to 13/64"). This figure may be compared with American practice, the Pennsylvania R. R. reporting a thickness of 6 mm (15/64") when new.

### Present tendency as to the selection of the type of box.

(Question 36.)

When the present tendency is examined in a general way, the Administrations consider that for high speed vehicles or vehicles set aside for high rated goods (for example refrigeration vans), it is worth while fitting roller bearings in spite of their higher price. This tendency is justified by the few heating cases and by the lower costs of maintenance.

There are cases however when the Athermos or ordinary boxes are preferred because of first cost.

In detail, there is some diversity which may be ascribed to differences in the stock and the services to be covered.

— As regards steam locomotives, some railways such as the English, Danish, Luxemburg and Norwegian state that they will retain plain bearings in their new building. Others, such as the S. N. C. B. provide roller bearings on high speed stock and the Victorian and New Zealand Railways will fit them to all new locomotives. The S. N. C. F. report they would use roller bearings if they had to order steam locomotives.

— As regards electric locomotives the Athermos box is widely used on French locomotives. On railways such as the S. N. C. B., Norwegian, C. F. F., Australian, roller bearings are fitted to new stock. Most railcars are fitted with roller bearings.

— On electric motor coaches, some railways such as the British use ordinary boxes, others like the S. N. C. F. and C. F. F. use roller bearing boxes. On urban lines, the Athermos box is used on the R. A. T. P. (Paris Metropolitan) and roller bearings

on London Transport Executive future stock.

— In the case of carriages, some railways such as the British continue to use ordinary boxes or even waste packed boxes, as in the case of Belgium. Others use Isothermos boxes (Spain, South Africa, etc.). Others such as the S. N. C. F. will use roller bearings on vehicles in international service and on the remainder of their stock either boxes with improved brasses, or Athermos boxes or roller bearing boxes. Finally, many Railways such as the American, Danish, Netherland, Norwegian and Swiss report they have adopted roller bearing axle boxes for all new stock to be built.

### **Wear & friction resisting metals.**

(Questions 37 to 41.)

— Generally rubbing parts such as axle box guides are fitted with easily detachable parts in wear resisting material such as hardened steel or bronze. Good results are reported from the use of 13 % manganese steel (France, Holland and in England, the L. M. R. quote an example when the mileage as a result of its use has risen from 105 000 to 160 000 km).

The C. F. F. also reports good results with *plastic material* (see figs. 8, 9 and 10 of Mssrs D'ARBELA and FASOLI's report). Celoron is used on the Paris Metropolitan (R. A. T. P.) on the Sceaux line and asbestos base materials such as Mintex are under trial on Norwegian motor coaches and on the Victorian Railways (Australia).

The wear resisting materials just mentioned *oppose the development of longitudinal play* that is to say parallel to the track, play which is the determining cause of hunting. To oppose this play other methods are available of which valuable details have been supplied by the railways.

These very diverse arrangements can be classed into two groups. In the first, the friction between the parts is retained but an attempt is made to cut out the wear: in the second, all friction is suppressed and there is no longer any question of wear.

**FIRST CATEGORY : Automatic self-adjusting axle box wedges** of the Franklin type as used in America are fitted on the S. N. C. F. 282R locomotives with very satisfactory results. Adjustable wedges are also used on the Netherlands Railways to which is attributed in part the long mileage between repairs with their 460 class 4000 locomotives.

— *Axle boxes guided by large cylindrical pedestals.* — This system is used on the C. F. F. on their SWS carriage bogies and on the Re 4/4 electric locomotives. In this method, the largely proportioned cylindrical pedestals slide vertically in cylinders with oil dampers. There is practically no wear (fig. 28, page 603/65 and fig. 38, page 644/106 of the August 1950 *Bulletin*).

— *Axle box guide to a plate with india rubber between.* — In this system used on the F. S. electric motor coaches the india rubber, by its pressure against the box, resists the formation of play (fig. 12, page 1466/110 of Italian Report, *Bulletin* for July 1950.)

**SECOND CATEGORY: Rods with silent blocs.** — All rubbing is suppressed by using boxes guided by articulated rods with silent block bushes. One example of this system is in the French BB 8101 electric locomotives of the Alsthom make. There has been a substantial increase in the mileage between shoppings (see fig. 25, page 600 of the August 1950 *Bulletin*). An other example is that of the railcars, electric locomotives and carriages of the Italian Railways (fig. 13, Italian Report, page 1467/111 of the *Bulletin* for July 1950). This guiding by pinned rods or links is fairly widely distributed and is used by the Norwegian Railways and by the Paris Metropolitan (R. A. T. P.), which intend to fit it to its new rakes.

— *Guiding by plate springs.* — By connecting the box to the frame by a horizontal plate, we get frictionless guiding. Examples of this are given by the S. N. C. F. (fig. 30, page 612/74 of *Bulletin* No. 8, August 1950) and the F. S. (fig. 14, Italian Report,

page 1468/112 of the *Bulletin* for July 1950).

### Springs.

(Questions 42 to 46.)

Generally speaking, beyond care in construction, and control of the metal and its heat treatment no special methods have been taken to reduce spring failures.

The springs are usually made of ribbed steel. The British Railways (LNER) use ribbed steel plate for plate springs and Timmis section bars for coiled springs. The London Transport Executive shotblast the faces of the plates in tension and report that round bars for coiled springs are tested by Magnaflux, a control also used on the Victorian Railways (Australia).

The Norwegian and C. F. F. Railways report a tendency to give up round bars in favour of square or rectangular bars for bogie coiled springs as they find fewer cracks in service with these sections.

The *quality of the steel* does not cause any particular trouble.

Silicon manganese steel C = 0.5-0.6 %, Si = 1.8 to 2 %, Mn = 0.7 to 1 % is used or is under consideration by several railways. The British Railways (L. M. R.) has tried this steel and recently decided to revert to oil hardened carbon steel.

Certain Railways specify the chemical composition of the steel (S. N. C. B., British, Netherlands, Norwegian, Pennsylvania RR., etc.). Others are content with the mechanical requirements (S. N. C. F., F. S., C. F. F., etc.). The essential thing appears to be able to get a quality of steel that will be regular and constant so that the workshop procedure as to heat treatment may be laid down and the same results always obtained. This can be insured either by specifying the composition or by prescribing the heat treatment and the mechanical properties.

Certain steels are *oil hardened* (Carbon = 0.5 % approx.) others are *water hardened* (Carbon = 0.8 % about). The results obtained are similar but water-hardened is more widely practised.

The *buckling of springs* is generally done hot but good results are reported with cold buskling by two methods. The first incorporates a carefully fitted tightening key plate and is used by the C. F. F. on their electric locomotives and by the S. N. C. F. on steam locomotives (figs. 19 and 20, page 586/48 and fig. 27, page 601/63 of *Bulletin* of August, 1950). The second method used by British Railways (L. M. R.) on modern steam locomotives is by wedge and key.

### Rubber springs.

(Question 47.)

In addition to the well known use of india rubber for lifting and drawgear many applications of rubber are reported to the spring gear of locomotives, carriages and railcars. The rubber is used working alone, or in compression or in parallel with coiled springs acting as a damper of vertical movement.

The Italian State Railways have tested various arrangements described in the Italian Report (see fig. 19, page 1470/114 of the July 1950, *Bulletin*, showing the usual arrangement adopted of rubber working in parallel with a coiled spring). An other example is that of the C. F. F. on the SWS carriage bogie (fig. 38, page 64 of the August 1950, *Bulletin*).

A widely used application of india rubber is in conjunction with the spring hangers. The Netherlands Railways have used this on their 460 steam locomotives for many years without having to renew the india rubber. The reports give other interesting uses such as the support of the bodies of the S. N. C. F. electric locomotives BB 8001 (fig. 26, page 600/62 of the August 1950, *Bulletin*).

The use of india rubber is of value to damp out shocks and to absorb noise which on the railways and especially in carriages, railcars and motor coaches, are serious drawbacks. Without going to the complete solution, which is to run on pneumatic tyres, tried on several rakes of carriages

since 1948 by the S. N. C. F., there is a general tendency to incorporate India rubber in details of the suspension gear.

### Summaries.

1. *Tyre wear* determines generally the mileage between repairs to the running gear and frame.

— *Modern equipment* has made it possible to extend the mileage between repairs with a more intensive utilisation and in certain cases an increase in load and speed.

— *New rolling stock* is ordered for various reasons : saving in working costs, higher speed, greater safety, more comfort. The saving in maintenance costs, whilst not the overriding factor, enters into these reasons.

2. — *One piece wheels* have been tested by many Administrations. They avoid tyre movement and in the case of carriages, rail-cars and motor coaches, the wheels can be lightened.

The information on cost price of these and tyred wheels does not agree. It has to be remembered that the service conditions are different, and that the one piece wheel is not manufactured at present in Europe in large quantities. Heat treating of the tread is advised to get at least the mileage of tyred wheels or better, to exceed it. Increasing the resistance to wear and ultimately the possibility of repairing by welding are two benefits more readily obtained with one piece wheels than with tyred wheels, wherein the shrinkage stress alters the allowable working stress in the tyre. It appears desirable that the experience with one piece wheels be followed up.

3. — To increase the mileage between repairs and reduce wear with harder rails some railways use *tyres* of 90 kg/mm<sup>2</sup> (57.14 t. per sq. in.) quality.

— *Lubrication of the flanges or the rails* is desirable to reduce the reciprocal wear of these two parts. Most Administrations carry the lubricator on the engine. Many and various arrangements are used.

4. — *Independent wheels* have been tested by some Administrations (British Railways (L. M. R.), Italian State Railways and Swiss Federal Railways) but the wear was rapid and irregular. The use of such wheels at least under the conditions used in the trials is not to be recommended.

5. — *Roller bearing boxes* tend to be increasingly used in view of the reduction in hot boxes and the saving in maintenance. In the case of steam locomotives, the use of these boxes on the driving or coupled axles reduces wear, which results in an important increase in mileage between repairs.

The few incidents reported in connection with the journals can be ascribed to these journals being too small.

In view of the high price of roller bearing boxes, there are cases wherein other types of box can be preferred.

— When *roller bearings are fitted to electric locomotives and motor coaches*, devices to prevent the electric current from passing through the roller bearings are fitted.

6. — Amongst oil axle boxes other than of the classic type, should be noted the boxes with mechanical oil circulation, and on steam locomotive, boxes with two brasses completely surrounding the journal (British Rlys. (S. R.) and S. N. C. F.).

— Lubricator pads of oil axle boxes are improved by increasing the number of wool wicks and the use of wool of special qualities.

— The tendency in Europe is to use high tin *antifriction* metal for high speed locomotives and rolling stock. Rose metal or lead copper (Cu = 69, Pb = 30, Zn = 1) is widely used on the Italian State Railways on goods wagons.

These latter years, the tendency has been to use thin coatings of white metal not exceeding 3 mm (1/8") thick, but it is noted some Administrations are going back to a rather greater minimum of 5 to 7 mm (13/64" to 9/32").

7. — The upkeep of parts *subject to wear* is generally done by using detachable wearing plates. Valuable results have been reported in the case of oil axle box guide by using manganese steel (British Rys.) and by using plastic materials (Italian State Railways and Paris Metropolitan) or asbestos base material (Norwegian Railways).

— To improve stability and comfort, and reduce tyre wear, it is desirable to *prevent hunting as far as possible*. One way to achieve this is to avoid longitudinal play in the direction of the track between boxes and frame. Very varied methods of doing this have been used, which either reduce the effects of rubbing or suppress it :

- adjustable or self-adjusting axle box wedges used especially on steam locomotives;
- guides incorporating india rubber fastened to the frame;
- axle box guides in the form of vertical cylindrical pedestals sliding in fitted cylinders (fig. 28, p. 1817/177, August, 1950, *Bulletin*);
- axle boxes connected to frame by rods and silent bloc bushes (fig. 25, p. 1814/174, August, 1950, *Bulletin*) a solution used on several Railways;

— boxes and frame connected by laminated springs placed longitudinally (fig. 30, p. 1826/186 of the August, 1950, *Bulletin*) a variant of the preceding arrangement.

8. — *Buckling springs* is generally done hot. There is some extension in Great Britain, and Switzerland, and tests in France of the practice of fitting the buckles on cold.

— *Spring steel* should be obtained under such conditions that the same heat treatment in the shops will produce constant results. This can be got either by specifying the chemical composition or by specifying given characteristics to be obtained by a predetermined heat treatment.

— *Coiled springs* should have their surface free from defects. Some Administrations (C. F. F., Norwegian Railways) report fewer breakages with springs of square and rectangular section, than with round section bars.

9. — *Rubber*, widely used on buffing and drawgear is now being applied to the spring gear and connecting members between the body and frame of tenders, electric locomotives, motor coaches, railcars, and carriages.

## QUESTION VI.

# Comparative study of transmission systems between motors and axles of electric locomotives, electric motor coaches and Diesel-electric railcars.

## Effect on the track of the types of bogies and systems of motor suspension,

by Ch. HOFFET,  
Special Reporter.

### SUMMARY.

- A. Introduction.
- B. General Considerations.
- C. Transmission Systems.
- D. Bogies and Suspension Systems.
- E. Conclusions.
- F. References.

### A. Introduction.

Section 2 of the International Railway Congress Association has adopted at the Enlarged Meeting of the Permanent Commission at Lisbon 1949, the following text for Summary No. 3 of the Special Report entitled : « Electric Locomotives for Express Trains (120 km/h. and over) », presented by M. D'ARBELA.

« 3. The numerous systems of axle-drive in use appear to be still in a state of evolution, although constructors appear to prefer solutions allowing a certain liberty of movement between the ensemble of the toothed wheels in mesh and the axle or else the motor-shaft.

» The nose suspended motor is still in use and it is even being adopted in certain countries for new stock now being designed. » (1) (\*)

In order to establish the reasons which have led designers in different countries

to adopt one or other of the two main systems of axle-drive, it was decided to add to the agenda of the 1950 Session at Rome question 6, which is described in the title of the present Special Report.

A very detailed questionnaire has been submitted to all the member Administrations of the Association. The replies to this questionnaire have served as the bases to the reports of :

Mr. W. S. GRAFF-BAKER, B. Sc., Chief Mechanical Engineer (Railways) London Transport Executive (2), so far as concerns the following countries : America (North and South), Burma, China, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan,

Mr. J. Tapia, Ingénieur en Chef au Service de la Traction électrique of the Spanish National Railways, Madrid (3), for the countries mentioned hereafter : Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Portugal and Colonies, Rumania, Turkey and Yugoslavia,

and that of the author of the present report (4) for the countries hereafter : Germany, Austria, Belgium, Denmark, France, Norway, Netherlands and Switzerland.

We wish to take this opportunity of thanking all the Administrations which have facilitated the task of the three rapporteurs by taking so much trouble over their replies to the questionnaire. Equally we wish to thank Mr. GRAFF-BAKER and

(\*) The figures in parenthesis (...) refer to the references enumerated under F at the end of this report.

Mr. TAPIA for the elaboration of their reports and for their suggestions concerning the Special Report, and also all those others who have been kind enough to give us advice and help.

We recognise and are grateful for the confidence shown in us by those who have charged us with preparing a regional report and this Special Report.

### B. General considerations.

I. In the following paragraphs we have attempted to summarise the ideas expressed by the three rapporteurs and, so far as this is possible, to formulate conclusions reconciling points of view which appeared at first sight to be diametrically opposed.

The report of Mr. D'ARBELA (5) concerned only high speed electric locomotives. The replies to the questionnaire relating to the present question VI, refer to locomotives, motor coaches and Diesel electric railcars of which the maximum speeds vary from 40 to 180 km/h. according to type and the service for which they have been designed.

The great diversity in service requirements has resulted automatically in a considerable variety of constructional methods, both for the vehicles as a whole and for their component parts. This variety is even more marked by the fact that designers and Railway systems are basing their new designs on experience gained under totally different conditions from country to country and particularly with the definite object of producing vehicles requiring a minimum of maintenance, inspection, repair and depreciation.

It should be remarked at this point that the electrification of Railways and the construction of electric rolling stock are in the process of considerable change. This is why only certain of the numerous Administrations which were consulted have been able to reply to the questionnaire submitted to them. Those systems which have not replied do not possess vehicles of the types covered in the questionnaire.

II. The stability and steadiness of a vehicle should not be confused with the riding comfort. The latter can be appreciated for example by a driver in his cab, whereas the stability of the vehicle is the result of the various forces exercised by it on the track and the consequent reaction. It depends among other factors on the following :

- a) the state of the track;
- b) the speed;
- c) the state of the vehicle;
- d) the suspension of the vehicle;
- e) the inertia of the various moving masses and the axle load;
- f) other internal and external forces.

The analysis of these factors has been the subject of practical measurement and theoretical research on a number of Railways. It has not been possible up to the present to measure the forces between wheel and rail, although attempts have been made to evaluate these on the basis of measurements taken at positions remote from the actual point of contact. From the experiments made in the laboratory to verify the theoretical calculations and from practical tests on the track which have been made, data has been obtained which has made it possible to design new types of locomotive relatively quickly. The performance of these locomotives is now under actual study on a number of Railways (6). It has also appeared useful to co-ordinate the various studies made by different authors along these lines, as this course has already been taken in the past in certain international organisations.

III. The general tendency is to use locomotives with motor bogies, wherever possible with total adhesion, rather than the type with a rigid frame and carrying bogies as has been constructed in the past. The bogies of these new locomotives are generally similar in construction to those of motor coaches.

The following details have a considerable influence on the form of bogie con-

truction and on the method of drive employed :

a) *Axleboxes.* — In spite of their advantages in respect of the strength of motored axles, better riding, especially at the entrance to curves, and the greater accessibility of brake blocks, inside axleboxes are very rare. Outside axleboxes appear to be generally preferred as they are more accessible and are easier to inspect and to change. Certain Railways successfully use plain bearings and mechanical lubrication; but nevertheless roller bearing boxes are tending to become general. They require no maintenance and give excellent results provided that they are large enough and carefully fitted in the first instance.

b) *Driving Wheel Diameters.* — On locomotives with rigid frames and carrying bogies it has been possible to use driving wheel diameters up to about 1750 mm. The motors are generally mounted above the driving axle with the result that the centre of gravity of the locomotives is of the order of 1800 mm above rail level, which has certain advantages when entering curves. This arrangement is still specified today by a Railway operating in country subject to frequent flooding. With this exception all the Railways tend to use driving wheels of from 900 to 1400 mm in diameter, a figure which is limited by the room available below the body. As a result there is a considerable saving in total weight and the centre of gravity is of the order of 1000 mm above rail level which of course diminishes the risk of overturning when travelling around curves at very high speeds.

IV. As a general rule the simplest forms of construction are also the best; they require the minimum expense both initially and for maintenance and are easier to inspect and service. In the construction of Railway rolling stock it is unfortunately not always possible to keep to this rule. The designer is prevented by the loading gauge, the curvature of the track, the maximum permitted axle load, the total

weight, the available materials and by price, from following this policy. On the other hand he must guarantee that the vehicle will attain the performance specified. He is thus frequently obliged to avoid simple forms of construction which for example may be too large. A reduction in the size for the given purpose may cause such an alteration in the characteristics and functioning of the components that the designer is obliged to compensate by introducing modifications which may well affect the ultimate strength and wearing properties. We can cite for example the replacement of leaf springs by helical springs or torsion bars. The former are of course self damping by means of the friction between the leaves, whereas with the latter one is obliged to use some form of damping mechanism. It often happens also that a minor modification in the dimensions of a simple component which has given entire satisfaction in its original form so alters the good functioning of the component that there is in many cases no remedy but the adding of extra components either because lack of space or expense prevents a complete redesign. These among others are reasons why so much modern construction appears at first sight to be more complicated than necessary.

We permit ourselves to remark here that those Railways which have not yet used the more developed forms of construction are now in difficulties and in many cases admit the advantages of the later methods; on the other hand Railways which have already used these improved methods have never returned to the simpler original forms even for low powered vehicles.

V. Among the questions submitted to the Administrations must be mentioned that of the effect of electrification on track maintenance. The replies to this question are exceedingly diverse :

Certain Railways have confirmed an increase in the rail wear on account of increased speeds or greater acceleration, in particular the corrugation of the rail top.

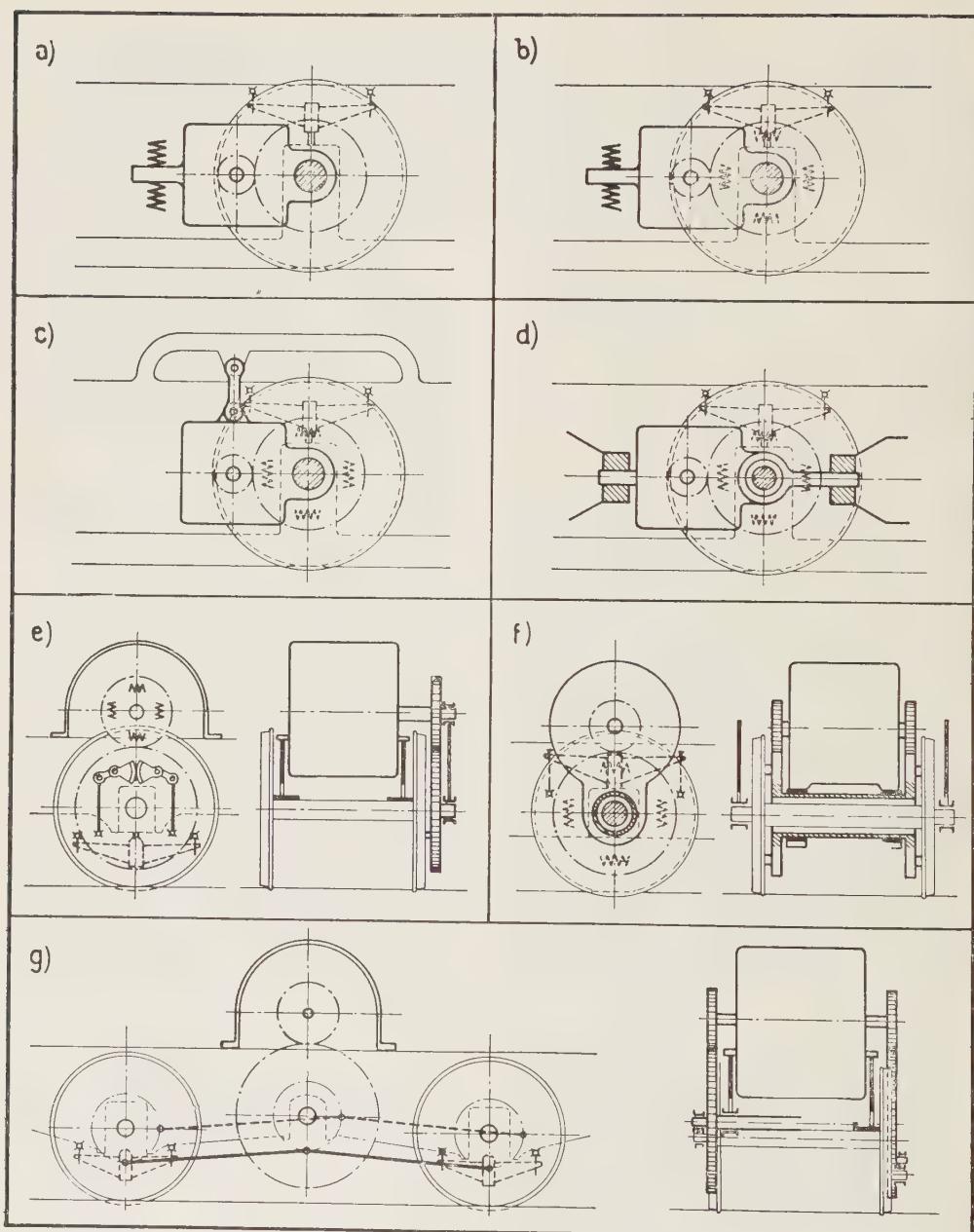


Fig. 1.

On lines with severe curvature, it has been found that the chamfering of the rail and wheel flange wear can reach alarming proportions; this in some cases has been successfully reduced by the use of flange lubricators or rail lubricators, or by means of transverse linkage between the bogies. The two methods can be combined. Other Railways have confirmed a decrease of rail corrosion in tunnels. Other Railways again have confirmed that rail breakages which were frequent under the effect of the hammer-blow of steam locomotives have been greatly diminished in spite of the use of nose suspended motors with rigid transmission. The operating conditions on the various lines before and after electrification are in some cases so different that it is impossible to give a universally applicable answer (7).

### C. Transmission systems.

I. Very numerous transmission systems exist. In the main these methods can be reduced to one or other of the types schematically represented in figure 1. These types are only examples, chosen to show up the differences of principle. They do not pretend to be superior to other similar forms of construction.

The methods in question must fulfil the following requirements :

a) transmission of the motor torque to the axle while giving to the latter a uniform rotational speed;

b) absorption of the vertical movement between the motor axle and the vehicle frame;

c) continuous correct meshing of the gear and pinion.

To satisfy these requirements the drive must be arranged in one of the following forms :

1) the motor can be solidly coupled to the driving axle and suspended on the frame at the opposite side by means of a suspension spring. This is the so called nose suspension, it is very widely used and has so been since the commencement of

electric traction, (Figure 1a.) The gear and pinion assembly does not in general possess any elastic component such for example as is shown in figure 1b, which has proved quite successful. One Railway uses non-resilient drive for its D. C. equipment and resilient drive for its A. C. equipment, both forms being in use with nose suspended motors.

2) In this case the motor is rigidly fixed to the frame and the transmission of the motor torque is by means of a resilient or articulated drive such as are represented in figures 1d, e, f and g. In his report Mr. TAPIA mentions a compromise which gives very good results and which is shown in figure 1c.

The arrangements shown in figures 1a, b, c and d, are used in motor bogie vehicles, being sufficiently low to enable them to go easily under the body. The arrangements shown in figures 1e, f and g, are by contrast employed on locomotives with rigid inside or outside frames. The arrangements shown at 1e and 1f are identical in principle except in respect of the position of the motor relative to the axle. The arrangement shown at 1g with coupling rods is employed in a new type of shunting locomotive and it has the well known advantage of reducing the slipping propensity which is noticeable on all vehicles with individual axle drive.

II. The nose suspended motor system with non-resilient drive is used by all Railways for horse powers below 500 and for speeds up to 160 km/h. This system is very simple. It has however the disadvantage that the track is subject to severe lateral shocks owing to the unsprung weight of the motor. This disadvantage increases with the weight of the motor (that is to say with the power transmitted) and increases also as the rails and flanges wear. This is the reason why several Railways do not use it except for very low powers. Mr. TAPIA cites the case of a Railway on which it has been found that the durability of the insulation of nose suspended motors is less than that obtained with frame

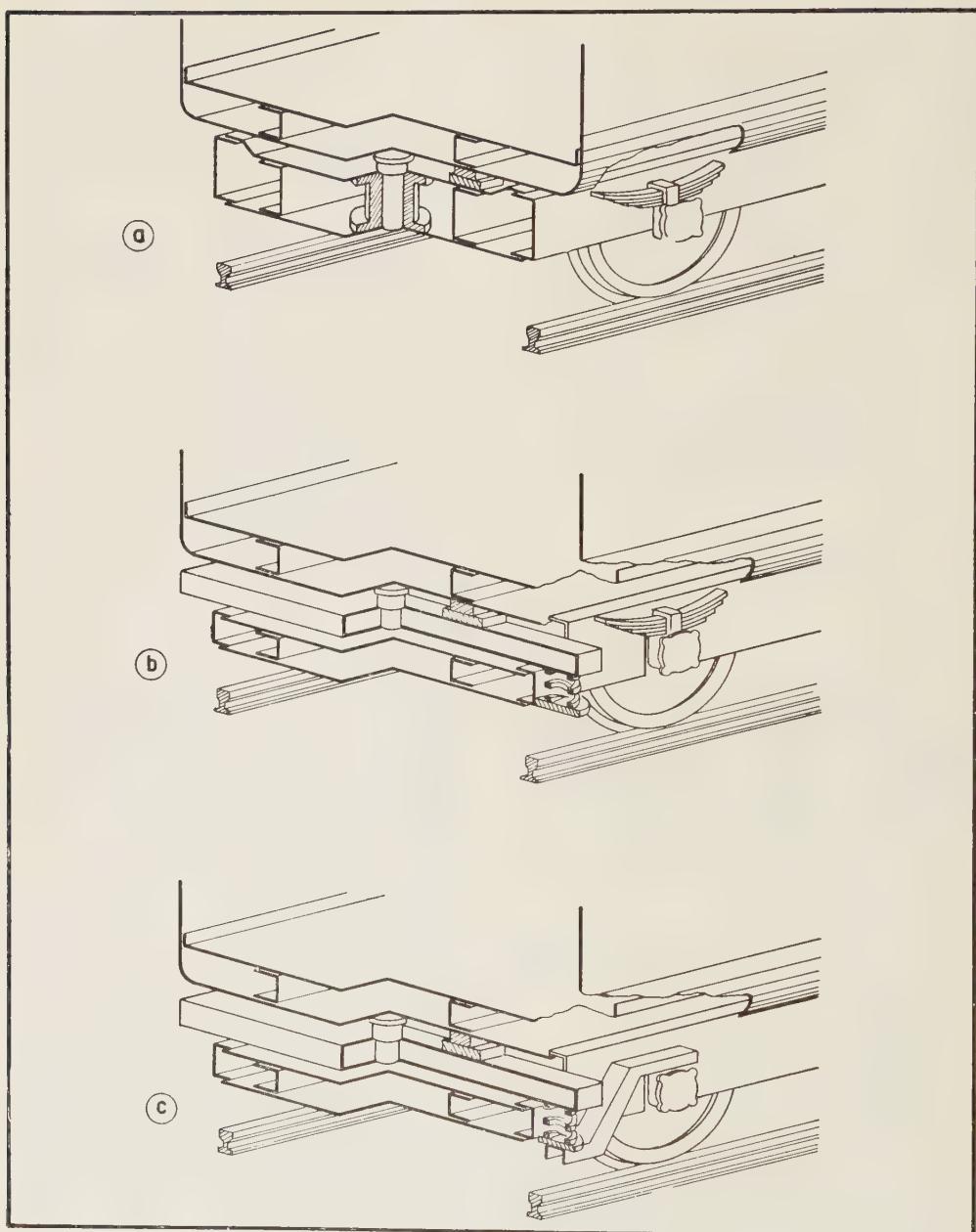


Fig. 2.

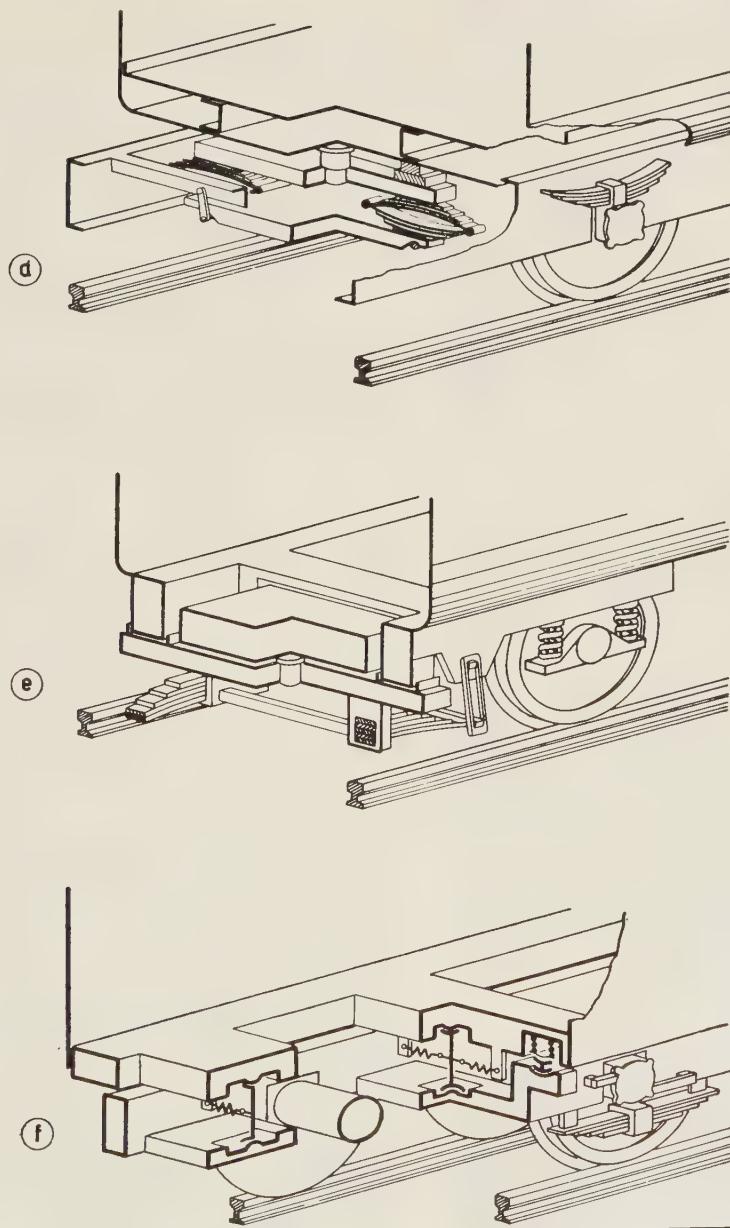


Fig. 2.

mounted motors. One Railway has under construction at the present time locomotives with this type of transmission with a horse power of 700 per motor; but provision has however been made for the possibility of replacing the gear and pinion assembly by a resilient drive in the event of the former arrangement proving unsuccessful in service.

A Railway which has a large number of C<sub>0</sub>-C<sub>0</sub> locomotives with 750 HP nose suspended motors and rigid transmission has confirmed very heavy track wear. It is intended that all future construction will embody frame mounted motors for all vehicles required to exceed 80 km/h., and for high powered locomotives irrespective of speed.

Nose suspension with resilient drive is used with success in regions B and C up to approximately 750 HP per axle.

Motors with rigid or resilient transmission are used in all three regions up to 1 500 HP per axle. Motors of these powers are both large and heavy and cannot be bogie mounted, they are of course only used in locomotives with a rigid frame and carrying bogies. It has seemed to us preferable to distribute the total weight and the total power over all axles and in consequence to use motors of a lower horse power (of the order of 1 000), and individual axle drive as is the case in most new construction (See B III).

Jackshaft and coupling rod transmission is nowadays only used for secondary services as it has great disadvantages except at the lowest speeds.

#### **D. Bogies and suspension systems.**

A large number of motor bogies exist which in the main have been derived from trailer bogie design. Figure 2 shows some of these schematically. In order not to encumber the sketches we have omitted the traction motors, and, if some of the known systems seem to be missing from this diagram it is in order to keep it within reasonable bounds. For the same reasons

we have also not thought it necessary to reproduce here the whole range of bogie frame constructional methods; that is to say channel section, pressed steel, cast steel, welded and riveted; nor have we thought it necessary to include the various springing systems used such as leaf, elliptical, volute and rubber. The various accessories such as shock absorbers have also been left out.

In principle every bogie consists of a frame merely serving to join axles to body. The motors are fixed to the bogie frame by one of the methods already shown in figure 1.

The simplest form of bogie is shown in figure 2a. The body is guided by a central pivot and sits on the bogie by means of transverse bearers. These latter may be fitted with springs to take up the play due to inequalities of the track. In spite of its simplicity this system cannot be used except on vehicles of limited speed, particularly for goods and shunting locomotives. At the present time preference is given to bogies with a swing bolster similar to those used in ordinary coaching stock. Some examples of this type are shown in figures 2b, c and d. The construction in these cases is more complicated, the object being better riding. The type shown at 2e has given excellent results and is tending to become general on a number of Railways. Mr. GRAFF-BAKER cites the case of a Railway where it has been found that bogies with one motored and one idle axle cause far less rail wear than bogies with two motored axles.

Certain Railways use 3 axle bogies, both with total adhesion and with the middle axle as a carrying axle. Figure 2f shows a bogie of the first type with frame mounted motors of 800 HP, a bogie in which a number of Railways are actively interested. It has the characteristics of automatic centering and resistance to longitudinal tilting. Its riding is extremely soft even at the highest speeds. It is impossible however as yet to determine its effect on the track; though older types of three axle bogies with 750 HP nose suspended motors have

caused very severe track wear. It is of advantage, though by no means general, to incorporate some of the following devices when designing bogies:

*a)* transverse linkage which has for its object the inter-action of the two bogies and by this means correcting the sharp angle of incidence of the guiding axle when rounding curves. As a result a considerable reduction in flange wear is effected. On straight track this arrangement also helps to prevent hunting of the bogies;

*b)* a method of reducing weight transfer which permits better use of the adhesive weight and consequentially of the traction motor torque. This can be done by various means such as :

1) a form of coupling between the two bogies, or

2) by the mounting of each bogie at two points situated on the longitudinal axis of the locomotive, one on each side of the bogie king pin, or

3) by means of pneumatic cylinders worked either automatically or under the control of the driver.

One can also reduce the effect of weight transfer by making the fixing point of the bogie traction arrangement as low as possible;

*c)* an anti-hunting device;

*d)* a friction or hydraulic shock absorber.

Hunting of the bogies may also be considerably reduced by using a long wheel base. We also recommend that the wheel base of the bogies and the distance between the bogie centres should not be multiples of one another, nor should they be a simple fraction of the rail length usually used. Failure to observe this simple rule often results in resonant effects becoming apparent at certain speeds. These have been known to cause failures or even derailments. It is advantageous to put the motors as low as possible in order that as much room may be made available in the body as practicable. Wherever possible the

motors should be placed towards the centre of the bogie in order that its moment of inertia may be kept to a minimum.

#### E. Summaries.

The three reporters, relying on the replies they have received to the questionnaires, unanimously agree to submit the following conclusions to section II of the Congress :

##### Summary 1.

The construction of Railway rolling stock in general and of motored vehicles in particular is limited by :

- a)* the loading gauge;
- b)* the permissible axle load;
- c)* the materials available;
- d)* the cost of construction;
- e)* the cost of maintenance, inspection and repair.

##### Summary 2.

There are a number of different transmission systems which can be used for all speeds up to 150 km/h. and for horse powers up to 1500 per motored axle. The choice of these will be dictated by local conditions :

*a)* if the track is sufficiently robust and well maintained, nose suspension may be used without great disadvantage;

*b)* if the track is weaker, it is desirable to use one of the systems employing resilient transmission and frame mounted motors if possible.

It should be noted that nose suspension inevitably causes lateral shocks to the track by reason of the unsprung weight of the motor. The progressive wear of rail and flange only aggravates the trouble.

##### Summary 3.

In order to avoid severe vertical shocks to the track due to high speeds it is neces-

sary to fit a resilient suspension system between the bogie and the body of locomotives by the use of arrangements similar to those long used on coaching stock and railcars. On locomotives, transverse linkages between bogies are tending to become general :

- a) in order to reduce side wear on the track and flange wear, especially on curves;
- b) in order to reduce hunting on straight track.

#### *Summary 4.*

The operating conditions with steam and electric traction differ too much from one another to permit a reasonable comparison of track maintenance costs to be made.

#### **F. References.**

1. *Bulletin of the International Railway Congress Association*, September 1949, page 671.

2. *Bulletin of the International Railway Congress Association*, April 1950, page 543/1 and June 1950, page 1145/141.

3. *Bulletin of the International Railway Congress Association*, July 1950, page 1529/213.

4. *Bulletin of the International Railway Congress Association*, August 1950, page 1633/281.

5. *Bulletin of the International Railway Congress Association*, May 1950, page 351.

6. *Journal of the Institution of Locomotive Engineers*, Paper No. 484, Dr. Gaston BORGEAUD.

7. *The Institution of Electrical Engineers, Convention on Electric Railway Traction*, 20 TH-23 RD, March 1950 : The effect of electric traction on the track, by F. C. JOHANSEN, D. S. C. (Eng.), M. I. Mech. E.

*June 1950.*

# SECTION III. — Working.

[ 656 .212 .5 ]

## QUESTION VII.

**Organizing methods to be used in large marshalling yards and terminals, to reduce to the minimum the cost per wagon shunted.**

**Determination of the staff and number of shunting engines needed;**

**Capacity and control of the efficiency of the marshalling yards;**

**Recording and numbertaking arrangements in the arrival and departure yards;**

**Statistics and traffic analysis by the control-room;**

**Braking and retarding arrangements;**

**The formation of trains for departure,**

by M. CIRILLO, Eng.,

Special Reporter.

## CONTENTS.

### FOREWORD.

1. *Measures intended to improve the general efficiency of marshalling yards :*

- a) Labelling the wagons.
- b) Preliminary notification of the composition of trains.
- c) Choice of train times.
- d) Allocation of the marshalling sidings.
- e) Harmonisation of the different operations in the yard.
- f) Reduction of causes of delay and idle time.

2. *Co-ordination and control of the work of the marshalling yard in order to obtain better efficiency. Choice and utilisation of the shunting engines :*

- a) Control post.
- b) Management of the yard.
- c) Shunting engines.

3. *Methods used and principles governing the work of marshalling yards :*

- a) Marking off on arrival and departure.
- b) Inspecting and repairing wagons.
- c) Shunting.
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- e) Making up the trains.

4. *Steps to be adopted if the traffic falls off.*

5. *The importance of the staff as regards the efficiency of marshalling yards.*

6. *Comparison and general control of the results obtained, and adaptation of the staff and equipment of the yard to variations in the traffic.*

7. *Summaries.*

### FOREWORD.

Endeavouring to find the best organisation for reducing to the minimum the

cost per wagon shunted necessarily leads to an examination of all the measures likely to lead, directly or indirectly, to economies in the cost of running large marshalling yards.

The question was dealt with by the three following reports :

Report (Belgium & Colony, Luxemburg, Norway, Denmark, Holland & Colonies, Switzerland, France & Colonies, Poland and Syria), by M. LAMARQUE. (See *Bulletin*, June 1950, p. 1093/23.)

Report (Italy, Spain, Portugal and Colonies, Rumania, Bulgaria, Sweden, Turkey, Greece, Czechoslovakia, Jugoslavia, Finland, Hungary and Austria), by M. CIRILLO. (See *Bulletin*, June 1950, p. 1227/75.)

Report (Great Britain and Northern Ireland, Dominions, Protectorates and Colonies, North and South America, China, Burma, Egypt, India, Pakistan, Malay States, Iran and Iraq), by M. E. W. ROSTERN. (See *Bulletin*, April 1950, p. 409/1.)

The object of this special report is to sum up these three reports and give the summaries derived from the enquiries made by the reporters in the different countries concerned.

The question as detailed, apart from details of the installations, dealt with large marshalling yards equipped in an up-to-date fashion, thus more easily comparable with each other from the point of view of the methods of organising the work. However details regarding other less up-to-date yards were also allowed, as much useful information can be obtained therefrom.

From the replies as a whole received to the questionnaire sent to the different Administrations, it is apparent that there is a certain uniformity both in the methods followed and in the principles retained, especially as regards the organisation of the work, the use made of the staff and engines, and the adaptation of resources to variations in the traffic.

The differences found between one country and another as regards the practical application of similar principles and methods often depend upon the conditions in the yards, whose installations and

services are not always comparable. The same applies to certain details of the organisation or special measures introduced on certain railways for local reasons.

Taking into account the agreement on the most important points, we have collected together in a few paragraphs (very concisely) the practically unanimous opinions of the Administrations consulted.

The different modalities as regards execution, to which at times it seems opportune to draw attention, will bring out the usefulness of solving the same problem in different ways according to circumstances, and local and traffic characteristics.

Having said this, we will go on to consider the measures adopted by most of the Administrations consulted, which we have grouped under the following six headings :

### 1. Measures likely to increase the general efficiency of marshalling yards

The proper organisation of the work of a large marshalling yard depends on a great many factors, some of which are extraneous to the yard.

#### a) Labelling wagons.

Nearly all the Administrations consulted have adopted some method of labelling wagons, in order to make it easier for the yard staff to recognise what siding the wagon should be shunted to, and also to assist them in making up the trains. Amongst the details given on the labels, the destination station is always indicated, and in the case of the more important places, this can be printed on the label.

In some countries, a bold number or coded index figure is added to the label, readable at a distance, to aid the staff in ascertaining the sidings on which the wagons are to be shunted, making it possible for the staff carrying out the preliminary operations to take the necessary steps immediately with practically no possibility of error. This system also facilitates making up the trains.

Some countries also use different coloured labels to enable the staff to recognise when

the wagons are loaded with perishable goods, fruit, express parcels, livestock, etc. Other countries use labels of various colours to show the different routes by which wagons are to be sent.

b) *Preliminary notification of the composition of trains.*

Most Administrations have made provision for giving their marshalling yards preliminary notification concerning the load and composition of trains.

The type of notification — sent by telegram, telephone or by means of the « dispatching » — varies from country to country. For example, all the trains may be notified, or only certain trains, details being given of all the wagons or rakes to be sent to a given place, or merely of the most important rakes.

In addition, the information given in this preliminary notification may be more or less detailed. Some countries merely state the number of wagons for each destination, whilst in others a great many more details are given: total number of wagons and pairs of wheels, gross weight of the wagons, kind of goods (especially in the case of perishable goods, livestock, fragile goods), urgent or registered wagons, etc.

The Administrations making use of this method are unanimous as regards its advantages; the marshalling yard knows in advance all useful details concerning the composition of the trains expected and can take the necessary steps before they arrive. In particular, it makes it possible to decide the most suitable reception siding according to the composition of the train, and the necessary steps taken to send on certain registered wagons without delay, to make provision for running the necessary extra trains, or if necessary suppress certain regular trains, and decide the best utilisation of the engines and driving and train staff. In certain cases, as in Luxembourg, such notifications are sent beyond the frontiers of the country and are regularly made in the case of trains exchanged with neighbouring countries.

c) *Choice of the train timetables.*

Amongst measures extraneous to the yard, it is generally recognised that it is necessary to time the arrival and departure times of the trains so as to facilitate the work of the yard and ensure the rapid transit of the wagons, although it is not possible to base the timetables solely upon the requirements of the yards.

There may in fact be two obstacles preventing the goods timetables being completely adapted to the best work output of the marshalling yards. The first obstacle is due to the fact that as passenger and goods trains generally have to use the same lines, the latter are nearly always subordinated to the former. Frequently — especially on the most important lines — the times when goods trains are allowed to run during the day are very limited, in fact nil in certain cases.

The second difficulty in the way of preparing timetables meeting the requirements of the marshalling yards is due to the different kinds of trains themselves, according to the service they have to assure, which makes it difficult to regulate their arrival and departure in a uniform manner. There is for example an essential difference between through and stopping trains, the latter being dependent upon the commercial requirements of the intermediate stations at which they have to pick up goods.

In any case, taking these difficulties into account it appears that all the Administrations consulted agree upon the following principles :

— the goods timetables must be so arranged that they run in the available intervals;

— arrivals and departures must be spaced out as evenly as possible, in relation to the capacity of the installations (reception, marshalling, making up and departure sidings), so as to reduce to the minimum the time wagons remain in the yard;

— the times of the stopping trains must take account of the hours at which the

stations and adjoining yards are open (local yards, private sidings, harbour quays, etc.) so that such places can be served at suitable times for loading and unloading wagons. For example, the stopping trains normally arrive in the marshalling yards in the evening and leave these yards in the early morning;

— the through trains must be timed in such a way that they arrive at the marshalling yard in time for the wagons to be cleared by the morning stopping trains, and leave the yard at times enabling the wagons brought in by the stopping trains in the evening or at the beginning of the night to be sent on;

— in all cases, the proper utilisation of the locomotives and train staff must not be overlooked, especially in the case of routes where there are several trains in the 24 hour period.

*d) Allocation of the marshalling sidings.*

Careful allocation of the shunting sidings is of very great advantage as regards the work and output of marshalling yards. All the Administrations consulted agree on this point, as well as on the advisability of using each siding for one purpose only, if they are sufficient in number and length to cope with the traffic. However, if in principle the allocation of the sidings is fixed, in actual fact it is not always possible to follow this criterion. Certain large marshalling yards have a few sidings which can be used for several purposes, according to circumstances and traffic requirements; it may happen that the same siding is used for different purposes at different periods of the day.

The allocation of the sidings is undoubtedly one of the most delicate and important factors from the point of view of the proper output of a marshalling yard, and depends upon local conditions as well as the experience and professional skill of the yard management.

In any case, although it is not easy to lay down any general rules in this connection, it appears advisable to allocate :

— the longest sidings to rakes collected by the longest trains;

— the best running sidings (generally those in the centre of the group) to empty stock;

— one or two sidings for damaged wagons.

*e) Harmonisation of the work of the yard.*

In most countries, the marshalling yard services are based on a working plan drawn up whenever the services have to be altered, which takes into account the times of the trains and the succession of operations in connection with shunting, making up the trains, etc.

Obviously, in practice, the expected conditions do not always materialise, nor are they always similar, which necessarily leads to modifications in the programme and the adoption of measures which cannot be settled in advance. This is where the managerial staff (or control post) must take steps to see that all the different operations run smoothly.

Nevertheless, the succession of certain operations, apart from special circumstances such as train delays, the running of special trains and suppression of regular trains, must as far as possible be done according to rule, in order to reduce to the minimum loss of time and the number of men required. Within this framework, it appears necessary to lay down the order in which the different operations shall take place, as well as to co-ordinate the work of the yard (reception, marking off, technical inspection, preparation for shunting, making up, shunting, etc.). In this way certain operations can take place simultaneously (for example marking off and inspecting wagons in the reception sidings), whatever modifications may have to be made in the movement of the trains or in the working conditions of the yard.

Naturally, the task of following and harmonising these operations as well as all the other work — especially the shunting — in the different parts of the yard belongs

to the yard management (or control post, which will be mentioned further on).

f) *Reduction of the causes of delay and idle time.*

The output of a marshalling yard also depends on the suppression or reduction of the causes affecting the regularity and rapidity of the service. This is why the harmonisation of the preliminary operations before shunting, the choice of the shunting engines (type, power) and the rational organisation of their refuelling, the rhythm of shunting taking place at a speed well adapted to the conditions in the yard, the methods of braking and skid braking used, the regulations about making up the trains, etc. have a decisive importance in keeping the work going without delay. On the other hand, it is also necessary to avoid as far as possible any incidents during shunting (overtaking, shocks, damage), the interruption of the shunting to refuel the engine, to push wagons on, etc. as well as other idle time due to various causes.

All the Administrations agree in principle on this point, and each endeavours to obtain the most satisfactory results by making use of methods, which may differ from railway to railway, which will be mentioned later.

**2. Co-ordination and control of the work of the marshalling yard in order to obtain the highest efficiency. Choice and utilisation of the shunting engines.**

All the Administrations consulted recognise the need for co-ordinating the whole of the operations taking place in different parts of a marshalling yard, to keep a constant check on the situation and to adopt appropriate measures according to circumstances, in order to obtain the highest possible output of work. With this end in view, a preliminary work programme is generally made out at each change of shift, which covers all foreseeable variations of traffic (seasonal, weekly or

daily), adapts the personnel and the locomotives of the various yards to these variations and co-ordinates their work.

Nevertheless, it is necessary to place direction and co-ordination of all the yards in the hands of one single controlling body, which will be able to follow constantly the development of operations and to adopt measures appropriate to the varying circumstances.

This principle established, its practical realisation will differ from country to country. In fact, whilst some Administrations have set up a special organisation known as « *control posts* », others have made the ordinary managerial staff, or one or two members of it, responsible for these duties.

a) *Control post.*

Where they have been set up, control posts are manned by a single employee (under or assistant yard manager) who is in direct communication by telephone with all the main parts of the yard, i.e.: the reception, marshalling and making up groups of sidings, the switch and brake posts, etc. The post is also in communication with the locomotive shed, the train staff office, the inspectors, and if necessary the men responsible for the traffic in the neighbourhood of the yard, as well as with the « *dispatching* » on the sections of line near the yard.

The man on duty in the control post (who may be assisted by one or two other employees) being thus able to keep himself informed of the position in the different parts of the yard, can follow and regulate the reception of the trains, the operations in connection with shunting, the utilisation of the shunting engines, the making up of the trains, the service of local sheds, the running of the trains and shunting within the yard, etc.

This enables him effectively to co-ordinate the work in the different parts of the yard, especially as regards the adaptation of the shunting engines and staff to the volume of traffic; he can arrange for

reinforcements or decide to reduce the number of engines and employees, according to circumstances; he must also make it his concern to see that registered wagons are sent forward as rapidly as possible, as well as any wagons that have been delayed, and that orders concerning the allocation of empty stock, etc. are carried out. The control post can also be responsible for regulating the running of the trains near the yard, receiving announcements of the composition of trains, and running extra trains on his own initiative or by agreement with the respective operating department offices. The man in charge of the control post (known in some countries as the « regulator ») is provided with a blackboard on which to write up the number of wagons on each reception and shunting siding; he keeps an actual graph of the train arrivals and departures, of the shunting operations, and sometimes of the occupation of the sidings, and keeps the special train diagram up-to-date.

Experience acquired in those countries, who have set up control posts, shows that such an organisation is very useful, from the point of view of increasing the output and quality of the work of a marshalling yard, especially in very large marshalling yards with extensive and scattered groups of sidings. In such cases, the cost of installing and operating such posts are justified.

*b) Management of the yard.*

When there is no special control post, the responsibility for co-ordinating and controlling the different activities of the yard belongs, as we have already said, to the yard master or another managerial official, specially nominated, who is generally assisted by other employees. In such cases, apart from the different organisation, the object in view being the same, the responsibilities and duties of such an employee are very similar to those of the man in charge of a control post.

*c) Shunting engines.*

Generally, the choice and power of the shunting engines used in the marshalling

yards depends on the tonnage of the trains coming in, and the rakes to be shunted or hauled in the different parts of the yard, as well as the slope of the gradient leading to the hump and the marshalling, making up and departure groups of sidings.

The engines used for shunting must also be powerful enough to push the corresponding rakes at the shunting rhythm. In addition, the shunting engines must meet the following requirements :

- rapidity of acceleration and starting;
- adequate braking, preferably on all the wheels, so as to get maximum adhesion;
- easy to handle and simple to drive, especially in reverse;
- good visibility both fore and aft.

Acting on these principles, all the countries have adopted suitable locomotives, most of which are steam engines. But some Administrations have introduced very successfully Diesel-electric locomotives of varying powers (330-680 HP), which have an appreciably higher output than that of steam locomotives of equivalent power.

In addition to its superior technical characteristics (easy to drive, rapidity in starting and running, ability to develop its maximum power at any moment), the Diesel engine also makes it possible to obtain great economies, especially from the point of view of staff, fuel and maintenance costs.

Actually only one man is needed to drive it, and the consumption of fuel is very low, especially because of the possibility of switching off the engine when the locomotive is not working. There is the additional advantage of doing away with interruptions for refuelling, since Diesel engines only need refuelling at intervals of several days. Generally, it is only necessary for the engines to go back to the shed once a week for a few hours; the maintenance of Diesel engines generally only takes place at intervals of 8 to 10 days.

When steam locomotives are used, it is impossible to avoid having to refuel with coal and water; all the Administrations consulted have done everything possible to

reduce the interruption to the work due to this necessity to the greatest possible extent. In the largest marshalling yards, the continuity of work is often assured by the use of an auxiliary locomotive, which replaces the different locomotives in turn, as they return to the shed to refuel. In other yards, refuelling is carried out without using an auxiliary engine, making use of periods when work is at a standstill (such as during changes of shift, or during breaks for meals).

Generally the engines only return to the sheds to refuel with coal, water being obtained from suitably sited water towers, but sometimes — especially when the sheds are some way away — a small stock of coal is kept near the place where the engines are working.

Finally, some Administrations use electric shunting engines, and in this case the question of refuelling does not arise.

Train locomotives are not generally used for shunting in marshalling yards, although they can be used if necessary for a few auxiliary shunting operations of limited duration.

In many of the countries consulted, the steam shunting locomotives are driven by two men, whereas — as we have stated above — only one man is normally used on Diesel locomotives; this is also the case with electric locomotives.

The shunting output, i.e. the number of wagons shunted per shunting locomotive hour varies a great deal, according to whether each part of the yard is considered separately, or the work in the yard is taken as a whole. For this reason the information supplied in this connection cannot be compared except as regards the same yard at different periods.

The work of the shunting locomotives is generally regulated by a programme prepared in advance, taking the traffic at each hour into account. In practice adaptations to circumstances are necessary when the actual requirements are found to be lower than those for which provision had been made.

The yard management or control post, on site, and the managerial offices keep a constant check on the use made of the shunting engines, and take steps to adjust the engines to the actual work.

### **3. Methods used and principles regulating the special operations carried out in marshalling yards.**

We have already mentioned the need for a wise harmonisation of the different operations carried out in the various parts of a marshalling yard, in order to obtain a high output from the equipment and staff of the yard. But the results obtained will not bear fruit unless the organisation of the operations in question is made as rational and economic as possible.

For this reason, all the Administrations consulted have prepared regulations and investigated the best way of organising the most important operations carried out in the yard, which are the following :

- marking off on arrival and departure;
- technical inspection and repair of wagons;
- shunting;
- braking and skid braking;
- making up the trains.

#### *a) Marking off on arrival and departure.*

The marking off is done in all large marshalling yards.

Marking off on arrival takes place in nearly every case at the reception sidings and marking off on departure on the making up or departure sidings.

As regards marking off on arrival, the methods used are very similar : the marker off receives the waybills from the guard and proceeds to identify the wagons. On some Railways he also prepares the shunting lists, and if necessary marks off the wagons with chalk, whilst on other Railways the shunting lists are prepared by another employee.

In countries following this latter practice, the recording of the details of each train from the waybills is done in the office. Some countries, in particular Great Britain,

record the wagons on arrival and departure only in a few special cases, being of the opinion that the extra staff required for this work is not justified in all cases.

The identification of the trains on departure is generally carried out by the marker off, who prepares the records of trains leaving. In some countries, on the other hand, the train records are prepared by the guard, without any assistance from the marker off.

In comparing the different methods, it appears that it is advantageous to make the markers off responsible — as far as possible — for preparing the shunting lists (or chalking up the wagons when no such lists are made), thus relieving other employees of this duty.

As regards regulating the work of the markers off, there is no standard method. In some large yards, where the use made of the men is based on a working programme, the markers off are under the orders of an official who regulates their work according to the actual conditions under which the trains come in and are made up; but generally, when there is a control post, the work is regulated by the post; otherwise the work of the markers off is controlled by the yard management.

It appears that it might be advantageous to regulate the work of the markers off in the very large marshalling yards, according to a programme prepared in advance, although certain modifications would have to be made to such a programme according to actual circumstances.

The transport of commercial papers and documents within the yard is generally done by the markers off and other employees on foot or making use of any available form of transport (bicycles, engines, etc.). But in some large yards, that are very up-to-date and well equipped, there are pneumatic conveyors which, apart from the cost of installing and maintaining them, have the advantage of greater speed of transmission and enable some savings in staff to be made.

#### b) *Inspection and repairs to wagons.*

Generally, the technical inspection of wagons is done on the arrival of the trains in the yard (on the reception sidings) and before trains leave (on the marking up or departure sidings).

The first of these inspections is undoubtedly the more important, as discovering any damage to wagons before they are shunted makes it possible to carry out repairs on site (when the damage is slight) or to shunt them onto the sidings reserved for this purpose, which avoids the lengthy and costly shunting which would be involved if the damage were only discovered on the shunting sidings. For this reason, all the Administrations have adopted this method to some extent, in spite of the additional staff costs it involves.

The second inspection is generally considered necessary to discover any damage which might have been sustained during marshalling, or which was not noted during inspection on arrival.

As regards the percentage of wagons that have to be taken out, compared with the total number of wagons dealt with, the highest number naturally relates to damage discovered on the reception sidings, but the corresponding figures, like those concerning the proportion of wagons withdrawn on arrival and on departure, vary considerably from country to country; consequently it is not possible to make any useful comparisons.

In general, on most of the Railways consulted the work of the inspectors is based on a programme prepared in advance according to the normal order of the regular trains. The adaptation of the work to the actual order of the trains and as regards any special trains is done by agreement between the Chief Inspector and the Yard Management or control post. In any case, quite apart from any working plan, it is always necessary to have constant contact between the management of the yard and the inspectors, so that the men can be used wherever they are needed. The best organisation in this connection is

obtained in those yards where the man responsible for the inspectors is in close communication with the yard control post, and especially when he is attached to this post.

Nearly all the countries consulted have set aside one or two sidings in the marshalling group for damaged wagons or those whose loads need adjustment. However, the use made of such sidings varies from yard to yard, because in some of them small repairs are not made on site, but on the contrary the wagons are removed to another siding, or in some cases to a repair shop near by.

In any case, if the installations are such that it is possible to carry out the work without any shunting onto adjacent sidings and without danger to the staff concerned, the carrying out of small repairs and adjustment of loads on the sidings where the damaged wagons have been shunted seems to be the best plan.

#### c) *Shunting.*

According to our investigation, the enquiry into the shunting operations in the different countries was intended to establish on the one hand the best methods of carrying out these operations, and on the other the measures and precautions to be adopted to avoid — as far as possible — all the causes of irregularities and delays. We have already mentioned the importance of the preliminary work before shunting, i.e. the identification of the train upon arrival, the inspection of the wagons on the reception sidings, uncoupling the wagons or cuts, etc.

Obviously, if all these operations are carried out according to a rational method, ensuring in particular that some of them are done simultaneously, the general output of the yard will be appreciably improved.

For this reason all the Administrations have developed methods, which are very similar, to avoid loss of time, and to reduce to the minimum the time elapsing between the time the train arrives at the yard and the time it is shunted.

Generally, the inspection of the train on

the reception sidings takes place at the same time as the identification of the train by the markers off who sometimes also prepare the shunting lists and programme (or mark off the wagons, or some of them, with chalk).

The inspectors label or chalk up any damaged wagons or wagons whose loads need adjustment, which have to be shunted to special sidings or to the shops.

The uncoupling of the wagons, disconnecting the brake pipes and emptying the train pipes is carried out according to the shunting plan; these operations are done by one or two shunters.

The preliminary operations may also include the marking of certain wagons (fragile goods, livestock, registered, etc.) which must be shunted with special precautions, or are not to be shunted.

Several factors contribute to assuring the regularity of the shunting and its greatest efficiency. First of all, the installations provided: rational profile of the hump, making use if necessary of two humps of different heights; length and profile of the marshalling sidings; existence of departure groups of sidings; suitable optical and acoustical communications; satisfactory lighting, especially in the region of the brakes, etc. But there is also the shunting programme based on maintaining as regular a succession as possible of trains arriving and leaving (for which the most suitable sidings are reserved), the judicious allocation of the marshalling sidings, the use of shunting engines of sufficient power to haul or push up to the hump the heaviest rakes, the co-ordination of the work of the different gangs, and the reduction to the minimum of any interruptions, whatever the reason to which they may be due.

As regards the shunting engines, more detailed consideration of which will be found later on in this report, some Administrations have obtained very satisfactory results by using two engines simultaneously for shunting, the second unit working whilst the first unit is getting into position at the head of another rake. As however

this is a costly operation, it must be used with a certain amount of prudence.

The speed at which wagons are pushed up the hump, which must never be excessive, depends upon the local circumstances in each yard (height of the hump, switch post equipment, etc., and atmospherical conditions, etc.) and must be regulated by clear and precise instructions given to the driver of the shunting engine (light or acoustic signals, and wireless which has been found of great value).

Delays and interruptions to the shunting — which all the Administrations consulted have endeavoured to reduce to the minimum — are due to various causes, some of which may be considered normal and others accidental; their length varies — sometimes considerably — from yard to yard.

In the first category can be included the obligation to send certain registered wagons forward without delay, the need to refuel the shunting engine, closing up wagons on the marshalling sidings, and the interruption of the shunting due to the arrival or departure of certain trains.

In the second category can be included accidents which may occur during shunting (overtaking, shocks, derailments), and mistakes (wagons getting on the wrong sidings). Wagons which have to be forwarded specially, the number of which is kept as low as possible, are generally sent forward by certain given trains, and placed at the head or end of the train, so that they can be taken off before shunting begins; they may also be shunted onto a special siding. These special cases, which may be costly in some cases, do not exist on every railway.

Interruptions for refuelling the shunting engines can have a considerable effect upon the output of the yard in the case of steam engines. When only a single shunting engine is used, it is generally refuelled at the most opportune moment (slowing down or interruption to the shunting for other reasons, breaks for meals or for changes of shift, etc.). If there is more than one

engine, an auxiliary engine generally does the work during the interruption. In any case, it is a good plan to have water towers in the yards and, if necessary, stores of fuel.

In principle the closing up of wagons should be done without interrupting the shunting, but this is not always possible in practice, even when using machines which run between the sidings to push the wagons on. However all the Administrations consulted endeavour to obtain the most satisfactory results though the methods used sometimes differ, as they depend upon local circumstances, from the use of the most suitable braking methods to the use of a second engine on the shunting sidings, or tractors. This latter method is not often used however as it means having wider spaces between the sidings and using additional men to drive and work the tractor. In the same way the use of capstans, especially electric capstans is exceptional.

Interruptions to the shunting due to the trains arriving or leaving on account of the layout of certain yards, cannot always be prevented. If the arrival and departure times cannot be arranged to reduce this inconvenience to the minimum, such interruptions should be made to coincide with breaks for refuelling the engine or its use to close up the wagons or for other purposes.

All countries take steps to prevent or at least reduce accidents during shunting. For example by adapting the rhythm of the shunting and the speed of the wagons to the special conditions of the installations (profile of the hump, height of fall, track brakes, etc.), and the visibility at the time, by the use of suitable skid braking it is possible to reduce overtaking and shocks to the minimum. Regarding the latter, skid braking is of the greatest importance.

To prevent derailments when the wagons are running through the points by switching them too quickly, it is essential that the neighbourhood of the switches be well lit, and if the points are operated electrically, each must be fitted with a track circuit. Derailments due to the state of the

track can be avoided by careful maintenance of the rails.

Precautions are also taken to prevent damage to wagons loaded with fragile goods or explosives, etc., which are usually distinguished by special labels and marked by the markers off.

As wagons going astray depend above all on the work of the staff used for shunting and the preliminary operations, great care must be taken in the training of the men concerned. Some Administrations have found that since route labels were introduced, the number of wagons going astray has been considerably reduced. On the other hand the steps taken to prevent overtaking, also prevent wagons getting on to the wrong sidings, since overtaking nearly always means that one of the wagons gets onto the wrong siding. The taking out of wagons that have got onto the wrong sidings in the marshalling sidings is generally done, according to circumstances, by the shunting engine or some other engine (the making up shunting engine in particular).

*d) Braking and skid braking.*

Only a few of the countries consulted have track brakes in some of their most up-to-date marshalling yards. Track brakes, intended to slow down and equalise very rapidly the speed of the wagons leaving the hump, are normally sited at the leading in to the marshalling group of sidings.

After the track brakes, there is generally only one line of skid brakes, hand operated, which can be used either to slow down or stop the wagons. However in some yards there are two lines of skid brakes, one to slow down and the other to stop the wagons.

There are no track brakes in most of the marshalling yards of the countries consulted; braking is generally done by hand operated skid brakes alone. It is then question of a space braking carried out as close as possible to the hump or continuous gradient; the skids are thrown clear of the track after the wagon has been slowed down, by pieces of rail (throw-off rails).

There are one or two successive lines to slow the wagons down or bring them to a stop by means of the skid brakes.

Sometimes the space braking is obtained by means of mechanical apparatus, worked from a distance like the track brakes. In some countries cuts of more than a given number of wagons must be braked by means of the screw brakes on the wagons.

Amongst the methods used, it appears that most of the Administrations consulted prefer braking to a stop at the end of the siding by means of skid brakes.

If the profile of the sidings is suitable, the type of skid carefully selected and the staff well trained, this method gives excellent results, especially as regards reducing the number of shocks.

The average percentage of wagons damaged by shock or derailment compared with the total number of wagons shunted varies from country to country, from 0.2 % to 2 %.

The number of men employed in the different countries to brake to a stop does not differ a great deal, since nearly everywhere one man is used for every 2 or 3 sidings, though there is some diversity as regards the number of men used for spaced braking.

*e) Making up the trains.*

It is hard to prepare a preliminary programme for making up the trains, as this depends upon the work of the yard each day, the resources as regards installations, shunting engines and staff available.

For this reason, whilst taking into account the fact that the operations of making up these trains must be completed in good time, so as not to delay their departure, considerable liberty is left to the yards in this connection, so that the work can be regulated from day to day in the best way, according to local requirements and the conditions obtaining at the time. If needs be, the making up of a through train can be brought forward or put off, according to the number of wagons on the sidings and their tonnage compared with

that laid down for the proper utilisation of the train.

On the other hand, it is necessary to regulate the making up, especially when it takes place on the actual marshalling sidings, so that the sidings can be cleared as quickly as possible, so that there is no risk of the yard getting congested.

The actual making up of the through trains presents no great difficulty, since it generally only involves adding or taking off a few wagons.

On the other hand, the making up of the stopping trains is a more difficult matter; it is generally done in geographical order, which involves long and complicated shunts. This is where the experience and technical skill of the shunters reveals itself; the Administrations consulted nearly all agree that the details of the making up should be left to the initiative of the men, though this does not always seem to be very opportune.

A special method, used above all in France, is that known as « simultaneous making up », by which it is possible to make up several trains consisting of several lots at the same time. In principle this method consists in sending all the wagons for all the trains which will occupy the same place or places in the train onto the same siding after they have been made up. « Simultaneous making up » avoids the shunting of wagons from one siding to another, since only one shunt or supplementary shunt is required. It also saves a great deal of time.

To use this method however it is necessary to have rather more sidings than the number of trains to be made up (one or two more as a rule).

As regards including vans in the trains, the van can be put at the head or end of the train, and this is done according to circumstances and local arrangements by shunting, or by the shunting or making up locomotive.

Generally the vans are kept together on a special siding in the marshalling group. The inclusion of wagons from another part of the yard is done in the same way.

#### 4. Measures to be adopted if the traffic falls off.

A fall off in the traffic, which may be temporary or last for a considerable period, is undoubtedly one of the greatest worries of a marshalling yard, whose installations and services have been created to deal with a constant and high rate of work.

At the present time, in view of the ever increasing competition which is taking a lot of traffic away from the railway, the problem is a very critical one in many countries. For this reason, if it becomes necessary to adopt measures leading to the greatest possible economies in the operation of the yards, rapidity of transport must on no account be sacrificed, as this is the essential factor as regards the quality of the service offered.

If the falling off in the traffic appears permanent, without being very considerable in volume and extent, most of the Administrations consulted agree that the output of the yard should be slowed down, thus making it possible to effect some economies as regards shunting engines and staff.

When circumstances permit, it is useful to close down one or more parts of the yard for one or two shifts. Although this measure leads to the greatest savings, it must be gone into very carefully if it is not to lead to an excessive increase in the average time wagons remain in the yard, and consequently lead to serious delays in the transport and delivery of goods. In such cases it is sometimes necessary to revise the timetables, if full advantage is to be taken of the measure; without upsetting the fundamental organisation of the work of the yard, this makes it possible to resume work at full swing as soon as the traffic picks up.

When the fall off in traffic involves a considerable decline in the volume of traffic over a long period, the problem of the steps to be taken to limit — as far as possible — the consequences of this crisis is a very delicate one and involves a thorough examination of the question

which not only varies from one country to another, but also according to the circumstances and characteristics of each yard.

Most of the Administrations consulted are of the opinion that it is not possible to close down an important marshalling yard completely and concentrate the work in another yard. On the other hand, in some countries there are marshalling yards of limited importance. Even in such cases it is not possible to lay down any general rules, but each case must be examined individually. In particular the question of which yards should be closed must be gone into very carefully, having regard to their geographical situation, the existing installations and from the staff point of view, and considering the new transit times it will involve and the burdens imposed on the other yards.

When it is merely question of a reduction in traffic on one or two days of the week, several countries have adopted measures likely to obtain economies. In most of the countries consulted, as no goods are collected or delivered on Sundays, the work of the yards is reduced on Mondays and sometimes also on Tuesdays (especially when the services are suspended for two days a week, as they are in some countries). Under these conditions it is possible to limit the number of regular trains run and suspend the services totally or in part.

The Administrations who have introduced this measure — whilst following the same basic criteria — have not all gone about it the same way, owing to the special requirements of each country or each yard.

In any case it appears that good results can only be expected by a judicious estimation of the increased transit times in relation to the savings obtained by the reduction in the number of shunting engines and men employed in the different services.

##### **5. Importance of the part played by the staff as regards the efficiency of marshalling yards.**

Analysis of the operations taking place

in marshalling yards has shown the very great importance, as far as the output of the yard is concerned, of the initiative and professional skill of the staff employed in the different parts of the yard.

From the management to the executives, the same good will, the same intelligent activity should inspire the different operations, in order to harmonise the work and obtain the best results from the resources available.

Very great care should therefore be taken in choosing staff for marshalling yards, the human element being the foremost factor as regards output.

All the Administrations have the greatest interest therefore in seeing that all the staff employed in marshalling yards are fully up to the job. In some countries the men employed in marshalling yards are carefully selected and trained, being given theoretical instruction and practical apprenticeship, during which it is possible to estimate their aptitude for the special work of the yards. Markers off, shunters, brakesmen, as well as other employees, all play an extremely important part, where the personal qualities of each man have a definite effect upon the output.

Another way of improving the output of work is the granting of premiums proportional to the importance, quality and quantity of work carried out by the different men. These premiums, which are intended to obtain a better utilisation of the staff, shunting engines and stock, have already been introduced by some Administrations who state they are satisfied with the results; since the system was introduced they have experienced an improvement in the quality and output of the work as well as a greater interest in doing the job.

Other Administrations, who have not yet adopted a system of premiums, inspired by the same principles, intend to introduce them in the near future.

In this way, a good management assisted by a staff carefully selected from the professional point of view and encouraged by suitable remuneration to put its whole

heart into the work, will be in the strongest position as regards obtaining the best possible output from a marshalling yard.

#### **6. Comparison and general control of the results obtained and adaptation of the staff and resources of the yard to variations in the traffic.**

Apart from the control of the work carried out from day to day by the management of the yard or by the control post, a more general control of the quality of the work and the output of the yard is in all cases carried out by the clerical staff at a higher level. This check can take place either in the yard itself, during the operations, or from reports and statistics prepared monthly or weekly, or other documents, regarding the use of the staff, the train and shunting locomotives, etc.

In particular this check deals with :

- fluctuations in the traffic and their characteristics (daily, seasonal, regular, etc.);
- the number of wagons and their average time in the yard, as a whole or for different services;
- the utilisation of the regular trains and the number of extra trains run;
- the number of shunting engines used, the hours spent in shunting, and their output (number of wagons shunted per locomotive hour);
- train delays on arrival and on departure;
- the total number of staff compared with the number of wagons dealt with;
- the extent to which the programmes for the dispatching and allocation of the trains are adhered to;
- amount of interruptions to the shunting, and the reasons therefore;
- the number of wagons damaged on arrival or after shunting, etc.

The analysis and comparison of these factors for one and the same yard at different periods makes it possible for the higher grades to follow the output and adapt the staff and resources of the yard to variations in the traffic to the greatest possible extent.

Thus, in the case of seasonal or weekly variations which occur with a certain regularity, the steps to be taken can generally be foreseen in the working programme of the yard (increase or reduction in staff and shunting engines, use of surplus staff in other services or letting them have their time off, running extra trains or suppressing regular trains, etc.). On the other hand it is more difficult to adapt the resources of the yard to variations in the traffic which cannot be foreseen and the length of which cannot be estimated in advance. In particular of there is a lasting reduction in the traffic, the maximum operating economies possible must be obtained, such as reducing the number of shunting engines, modifying the train programme, and if needs be closing down certain parts of the yard, as already mentioned under point 4.

#### **SUMMARIES.**

The information supplied and the opinions expressed by the different Administrations consulted, regarding the investigation of the chief measures likely to reduce to the minimum the cost per wagon shunted lead to the following summaries :

##### **I. General output of the yard.**

###### *Labelling wagons.*

- 1) The use by the consigning station of coded indications on the labels of wagons showing the destination station and legible at a distance facilitates, in countries of any size, the work of the yard employees and reduces the risk of wagons going astray.

###### *Notification.*

- 2) Preliminary notification of certain details of the composition of the trains coming in enables the yard to estimate and organise its work better.

###### *Timetables.*

- 3) Though the timetables must be fixed first of all in such a way as to ensure the best forwarding of the wagons and most

satisfactory services, they must also to the greatest possible extent take into account the highest efficiency of the yard, especially when there are insufficient reception or departure sidings.

*Allocation of sidings.*

4) Careful allocation of the marshalling sidings, based upon the installations of the yard and the kinds of trains to be made up with the wagons shunted onto the same siding, has a very good result upon the output of the yard.

*Co-ordination (and control) of the operations of the yard.*

*Adaptation of resources to requirements.*

5) Co-ordination of the different operations carried out in the yard is essential for good output.

This is assured in the first place by the preparation of preliminary working programmes or harmonograms showing the way the different engines and gangs of the various parts of the yard are to be used in each shift. These programmes, which differ from day to day according to the traffic, should regulate in particular the way the different preliminary operations before shunting are carried out simultaneously.

In addition, the concentration of all useful data in the hands of a single official with extensive telephonic communications throughout the yard makes it possible to harmonise and control all the work and adapt requirements to resources from day to day to the fullest possible extent.

To carry out these indispensable duties, the setting up of a control post which can follow the movements of the trains and engines very closely as well as the way the different operations are proceeding, is an excellent expedient in large marshalling yards, especially when these consist of several scattered parts.

*Shunting engines.*

6) The shunting engines used in marshalling yards must be of a suitable type

for the special work required of them. In non-electrified yards, the Diesel engine has proved its worth wherever it has been used, from the point of view of having a higher output and greater flexibility than the steam locomotive.

7) In the case of steam locomotives, it is necessary to take special steps to minimise interruptions due to the need to refuel or for maintenance purposes. It is often of value to install a fuelling post in the yard where water and coal can be taken on.

8) The use of train locomotives for shunting is not to be recommended, except in the case of certain special operations of limited magnitude.

9) The proper utilisation of the shunting engines, which is shown by the number of wagons shunted per hour, can lead to considerable economies; it must be followed from day to day by the management of the yard and by the control post, dealt with under point 5, if there is one.

**II. Efficiency of the special operations carried out in the yard.**

*Marking off.*

10) Most of the Administrations consulted consider that the marking off on arrival and departure is of special importance as regards the proper working of the yard, and care should be taken to see that this work is properly done. It appears advisable, whenever it is possible, to let the markers off prepare the shunting lists. Finally a certain amount of regulation of the work of the markers off may be useful in certain very large yards.

*Inspection and repairs.*

11) In general it is as well to make a complete inspection of the wagons on the actual reception sidings so that damaged wagons can be sent direct to a special siding when they are shunted; the second inspection, which takes place before departure, will then rarely discover any wagons needing to be taken out.

In the large marshalling yards, certain

marshalling sidings (the outer ones as a general rule) can be usefully allocated for very small repairs, so long as the essential safety precautions are taken.

*Shunting.*

12) The speed of shunting depends upon the installations, the prevailing atmospheric conditions (and, in some cases, the composition of the train to be shunted). These elements being taken into account, the speed selected should be the maximum speed which allows the wagons to run as far as the marshalling sidings with the greatest regularity and the minimum of mistakes and overtakings.

13) The driver, the man in charge of the hump, the pointsmen and all the men working on the shunting should be in close communication with each other, by means of optical and acoustical equipment and radio-electrical installations.

14) The battle to prevent lost time and accidents is of the greatest importance from the point of view of the general output of the yard. In particular care must be taken to reduce to the minimum any interruptions to the shunting, in particular by taking steps to deal with the refuelling of the engines on site, the closing up of wagons on the sidings, and the reduction of the number of wagons getting onto the wrong sidings.

*Braking and skid braking.*

15) Overtaking, shocks and damage must be reduced to the absolute minimum by suitable braking and skid braking methods.

In yards equipped with track brakes, the best solution in general is :

— on the one hand, to reduce the speed of the wagons, and to space them suitably by means of the brakes;

— on the other hand, to stop them at the end of the siding, immediately behind and as near as possible of the last wagon shunted, by means of hand operated skids.

In yards not equipped with track brakes, the spacing of the wagons is generally

assured by special apparatus or hand operated skids, which are thrown clear of the rails; the wagons are stopped at the end of the siding by hand operated skids as in the previous case.

*Making up.*

16) A general preliminary making up programme for the trains, adapted to day-to-day requirements, by the yard management, is extremely useful.

17) In most of the countries consulted, the making up of multiple lot trains is left entirely to the initiative of the men. It would however be desirable to organise this work on rational lines; with this object in view, some countries have already made use of « simultaneous making up », which saves about 50 % of the time previously required for making up.

**III. Economies to be made when the number of wagons to be dealt with is less than the full capacity of the marshalling yards.**

*Weekly reduction in the traffic.*

18) A weekly reduction in the activity of marshalling yards at the beginning of the week can as a rule be accompanied by important economies obtained by closing down for 24 hours at the most the two shunting and making up yards, the start and end of the shunting down being staggered by a few hours from one yard to the other. As such a measure always involves an increase in the transit time, it is necessary for each Administration to weigh carefully the needs of rapid transit against the necessity for making economies.

*Permanent reduction in the traffic.*

19) If there is a permanent falling off of the traffic, the necessary economies can be obtained either by reducing the shunting output, with a corresponding decrease in the number of men and shunting engines employed, or by closing one or more parts of the yard for one of the daily shifts, or

even two in exceptional cases. If the decline in the traffic continues or increases, it becomes necessary to reconsider the general problem of the transit times and the new duties of the marshalling yards that will be kept open.

#### IV. Staff.

##### *Training and selection of staff.*

20) The high output of marshalling yards depends to a very large extent on the professional skill and efficient work of the men employed there.

For this reason extensive professional instruction and the careful selection of certain specialised staff, in particular the skid brakesmen, has given excellent results, wherever it has been introduced.

##### *Output premiums.*

21) It appears advisable to interest the shunters in the output of work by introducing premiums, varying from day to day if possible, according to the quality of the work (less damage, delays, etc.) and the actual output obtained (number of men, shunting engine hours per wagon dealt with, etc.).

#### V. Comparison and general control of the results obtained.

##### *Output factors for the yard and their comparison.*

22) The factors most likely to give a measure of the output of a marshalling yard are:

- the average time elapsing between the arrival of a wagon in the yard and the time it is ready to leave;
- the number of wagons shunted per shunting engine hour;
- the total number of men employed in the yard compared with the number of wagons dealt with.

But these different factors are hard to compare as between one yard and another, and really are only useful for making a comparison between the output of the same yard at different periods.

##### *General control of the results obtained.*

23) The different grades must organise effective and constant control of the quality of the work and the output of the yard in every field. This control, which is based on the appropriate documents and statistics, must above all make it possible to adapt the different resources of the yard and the train services to the actual traffic requirements.

### QUESTION VIII.

**In view of the ever increasing weight of road competition, what are the most appropriate measures, apart from reduced rates, for keeping traffic by full wagon loads in the hands of the railway ?**

**Would not road transport at the end of the railway journey be justified in order to get direct contact with clients who are not connected up by railway sidings ?**

**Should not the road vehicles required to assure such transport be attached to centre stations, equipped with suitable handling equipment, from which the road transport services would start ?**

#### **Choice of the vehicles to be used,**

par P. MAROIS,

Directeur du Service Commercial de la Société Nationale des Chemins de fer français,

Special Reporter.

Three reports dealt with this question :

Report (Belgium and Colony, Denmark, France and Colonies, Luxemburg, Netherlands and Colonies, Norway, Poland, Switzerland and Syria), by Mr. GIRETTE (See *Bulletin*, April 1950, p. 325/1);

Report (America (North and South), Burma, China, Costa Rica, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iraq, Iran, Malayan States, Pakistan), by Mr. A. A. HARRISON (See *Bulletin*, May 1950, p. 775/39);

Report (Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Portugal and Colonies, Rumania, Spain, Sweden, Turkey and Yugoslavia), by Mr. Mario DIAS TRIGO (See *Bulletin*, May 1950, p. 809/73).

The importance of Question VIII included by the Railway Congress Association in the agenda for the 15th Session will be denied by no one. This question is in fact one aspect of the more general question all those concerned with the future of the railway, whether railwaymen or not, are

asking themselves : in view of the increasing competition of other methods of transport, what will be the place of the railway in a few years time in the general organisation of transport in the different countries ?

The reports presented in connection with Question VII show that it is impossible not to extend the discussion in this way. M. DIAS TRIGO in particular mentions in his conclusion the need to regulate road transport, and M. HARRISON, basing his views on the special experience of Great Britain in this field, devotes important pages of his report to the general organisation of transport.

In his opinion the real answer to Question VIII is divided into three parts :

*a)* Improving the services offered by the railway to such a level as is made possible by the price the users are prepared to pay;

*b)* Taking care to see that the capacity of the railway corresponding to a suitable service is fully utilised, so that the costs,

which do not vary with the volume of traffic, are well distributed;

c) Fulfilling condition *b*) by using railway and road transport for the traffic they are most qualified to deal with, with supplementary transport facilities in view rather than the question of competition.

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In most cases, it is impossible to think of railway transport without at least some form of terminal transport by road, and from the beginning the Railway Administrations have been closely concerned with the organisation of terminal transport. The importance of such transport becomes the more marked as road competition increases. In addition to the main transport by rail, all traffic requires supplementary operations on the part of the client: handling, packing, collection or delivery, etc., and it must be recognised that motor competition has laid particular stress on the importance of these supplementary operations, which can affect the whole question of transport from the client's point of view.

As far as traction itself is concerned, the road technique — as railway engineers know very well — costs four to five times as much as the railway technique, and if it were only question of transport from one station to another on a good railway line, the railway would be in an unassailable position. But although the small capacity of the road vehicle increases the cost price of the transport properly so-called, the road on the other hand profits by this same small capacity to individualize the transport and get the door to door technique with all its advantages from the client's point of view. Although the railway is economic in the case of transport over its lines, as soon as the distance of the transport falls to about 200 km (124 miles) (and in 1948 the average distance of transport over the French Railways was 258 km = 158 miles), the costs are doubled by the terminal operations.

Two consequences can be drawn from this fact:

The first is that if the railways have made considerable progress as regards the main part of the journey, they have not made sufficient efforts to deal with the question of terminal transport. And this is the very field in which most savings could be made.

The second consequence, is that the railway should, if it is not to be overcome by its competitors, undoubtedly develop door to door services. Undoubtedly such door to door service has long been obtained in the case of private sidings, and an important part of railway traffic is carried from one private siding to another (40 % on the French Railways); but not all railway clients have private sidings. Those, who have none, make it imperative for some new technique to be evolved which will give such traffic, most of which is carried by rail, the same advantages as the road.

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As regards the first order of ideas, i.e. the reduction of the cost of terminal transport, the reporters examined the value of concentrating the traffic in certain stations with haulage services organised at such well equipped station centres, and this question was one of those which the Congress proposed to discuss.

Opinions appear to be divided. Some are of the opinion that the additional cost due to the longer hauls from the station centres is not made good by the economies due to the shortening of the railway journey and the concentration of the traffic. But although extensive trials have already been made in the case of parcels traffic, the opinions expressed concerning the value of concentrating the full load traffic in such station centres are based on theoretical studies. The Administrations, who consider that practical trials should be made, or who, like Finland, have already started such trials, do not appear to have had sufficient

experience as yet for it to be possible to state at the present time whether such a concentration of the full load traffic is economic or otherwise.

In addition, it should be noted that various Administrations are not in favour of the railway organising haulage services for full loads. This has however been done in Finland for the last twenty years. Such services are also in operation in Switzerland and Tunisia, and in Sweden in the case of certain goods.

As regards the collaboration between the railway and haulage services, M. GIRETTE points out that the public hauliers have similar interests to the railway, since they both suffer from the competition of private motor transport. It appears to him that this community of interest should be profited by a partnership between the railway and public hauliers to obtain a reduction in the cost of door to door transport. This idea seems to have been put into practice in New Zealand where the railway has made an agreement with the Road Hauliers Union according to which the railway will not operate collection and delivery services in the towns so long as the road hauliers do not try to get licences to operate services competing against the railway.

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As regards the realisation of door to door services, the Reporters considered the different solutions adopted by the railways : containers, rail-road trailers, wagon-conveying trailers. Certain railways appear to have chosen one definite solution. The British and Netherlands Railways, for example, have developed the use of containers to the exclusion of all other methods. Others, such as the French Railways, whilst making a large use of the container, continue to experiment with other solutions. It does not appear to be possible to draw any definite conclusions as yet, and trials appear to be desirable. It should be

noted however that in the case of international traffic, at the present time the only solution which makes door to door transport possible over no matter what journey, is the use of containers handled by cranes, and the wagon-conveying trailer when available, since these are the only solutions making use of the ordinary railway installations without requiring any special equipment.

Finally, the different Reporters drew attention to the need not to overlook any other measures which might enable the railway to satisfy its clients and give them the desired conditions. From this point of view, speed of transport and perhaps above all timetables in line with the needs of the traffic — it being understood that such timetables will be regularly respected — are of obvious interest. The development of special wagons adapted to individual requirements is also desirable and likewise it is to be recommended that all possible facilities should be provided at stations for clients to carry out the operations involved. Those, who seem to have gone furthest along this road, are the British Railways who encourage delivery services from stations, and will undertake on behalf of clients the work of storing, book-keeping and distribution.

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In endeavouring to draw from the three Reports presented summaries which can usefully be discussed by the Congress, the following appear worthy of retention :

1) Some railways consider that the use of lorries for haulage services, by extending their radius of action, now make it possible to concentrate the traffic in a certain number of well equipped station centres, by using motor haulage services over longer distances, and that this organisation will definitely lead to economies.

But although many theoretical studies of this idea have been put forward, it does not appear to have been the object of

practical trials, except in the case of parcels traffic. It appears very desirable that such trials should be undertaken as soon as possible by different railways and the results published, so that everyone can profit by their experience.

2) The general opinion appears to be in any case that if the traffic is concentrated in this way in the station centres and the haulage services extended, it is necessary for the railway to have commercial control over such services, if there is to be no risk of losing the traffic at each end owing to competition.

3) The attention of the Congress should be drawn to the importance of the terminal transport as regards the cost of transport between clients who are not linked up with the railway. The reduction of the cost of such terminal transport is probably of greater interest to the railway than reduction in the cost of transport by rail.

4) Terminal transport can be assured by the railway itself, but the Reports seem to show that in the case of the full load traffic, such services are poorly used by clients who prefer private haulage.

5) Attention is drawn to the mutual interest of the railway and public road hauliers in defending themselves against private transport. This community of interest between the public haulier and the railway could surely be used to organise cheaper door to door services.

This question however does not appear to arise in certain countries, such as Great Britain and Bulgaria, where the regulations adopted have gone further in advancing the problem of the coordination of methods of transport.

6) Experience has shown the value of the door to door technique which is the essential advantage of the motor vehicle. The oldest solution to the problem on the railway is the private siding. It would appear to be to the interest of the railway to do all it can to increase the number of such

sidings. Certains railways appear to be in this respect much more ahead than others.

7) When clients are not linked up by private sidings, the railway does not seem to have taken sufficient interest to date in the other methods which enable the door to door technique to be obtained, using the railway for the main part of the journey. It would appear advisable to make great efforts in this direction.

8) This effort would involve not only capital investment, but also commercial organisation. Clients must find available at the railway station all the facilities obtained from its competitors, and the railway should collect and deliver goods just like the road haulier. It is found that when the railway confines itself to perfecting technical arrangements and informing its clients about them, it does not get any results. Experience in Great Britain, from this point of view in connection with door to door services, shows in the clearest way the results that can be obtained with a proper commercial organisation.

9) A certain number of solutions making door to door transport possible have been perfected : containers, rail-road trailers, wagon-conveying-trailers. It seems that up to date experience does not warrant the recommendation of one rather than another of these solutions. The different railways should continue their trials. It is not certain that a single solution can solve all the problems arising. In the end, it is the client who is the best judge of what suits him, and he should not be forced to adopt one solution rather than another when experience shows that they all have their uses. It is necessary however, for economic operation, only to have a small number of types of no matter what solution adopted.

10) In addition, it seems essential that the railway should so organise its operation that the wagons used for the transport of containers or rail-road trailers should have a good user.

Careful grouping of such traffic is essential if the cost is to be such that attractively low prices can be offered to clients.

11) In the fight against competition, the railway should not neglect other improvements to its services capable of inducing clients to choose it in preference to other methods of transport. Safety, rapidity and regularity of transport should all be increased. Timetables which enable the traffic to leave and arrive at the most suitable hours are of greater value than actual speed. For example, there is no benefit in saving a few hours on the transport of food-stuffs if this saving will not enable them to be available as soon as the markets open.

12) The building of special wagons adapted to special requirements is also another way of retaining railway traffic. Opinion seems to be divided concerning the value of including such special wagons in the ordinary stock, or encouraging the private firms making use of them to build their own.

13) It is to be recommended that all facilities be provided at railway stations that their size and layout make possible. The renting of sites and providing of handling gear are of the greatest interest.

14) Finally, the attention of the Congress should be drawn once again to the importance of the general organisation of transport. M. HARRISON recalls that the President of the British Transport Commission recently stated that « it is not inopportune to point out to commercial and industrial firms in general, and to those proposing to make use of private transport in particular, that public transport cannot carry on and be self-supporting unless it has a sufficient number of clients to whom it is in a position to supply a good service ».

If commercial and industrial firms make use of their own vehicles to transport the goods in question and only send the bulky and less paying goods by rail, there is no doubt but that the cost of public transport will increase in a way that in the end will be detrimental to general economy.

## QUESTION IX.

**Modern safety and signal installations (centralising apparatus for block system and signals). — Central electric apparatus with individual levers and « all relay » levers (all electric interlocking). — Automatic block-system with continuous current and coded current. — Light and speed signalling,**

by H. H. DYER, M. I. E. E.,

Special Reporter.

Three reports were presented :

Report (Belgium & Colony, Denmark, France and Colonies, Luxemburg, Norway, Netherlands and Colonies, Poland, Switzerland and Syria), by E. J. F. DERIJKERE. (See *Bulletin* for July 1950, p. 849/13.)

Report (America, Burma, China, Egypt, Great Britain & Northern Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan), by H. H. DYER. (See *Bulletin* for March 1950, p. 247/1.)

Report (Austria, Bulgaria, Czechoslovakia, Finland, Greece, Hungary, Italy, Portugal and Colonies, Rumania, Spain, Sweden, Turkey, Yugoslavia), by RIGO RIGHI. (See *Bulletin* for June 1950, p. 1389/41.)

Although a joint questionnaire was sent to all the Managements concerned, the three reports were drawn up in a somewhat different manner.

The object of this special report is to combine the information given in the three reports and to reach conclusions thereon.

Certain questions dealing with matters of principle and the methods of putting them into effect relating to the subject of these reports have already been raised at previous Sessions. The questionnaire for the subjects for the present Congress was drawn up largely with a view to being applied to electrified lines or to lines which are to be electrified.

At the present time when certain railways propose to invest large sums of money for the purpose of electrifying their lines and at the same time increasing the speed of their trains, consideration has been given to the development of colour light signalling and its adaptation to this new method of working. In addition, the increase in the density of the traffic which will result makes it necessary to look for means of obtaining very great rapidity in the setting up of routes in the signal boxes, while employing a minimum of staff and at the same time obtaining the maximum degree of safety.

Certain questions referring to the technical details of equipment design, either in the signal box or out on the line, have also been brought forward for consideration.

Most of the Railway Administrations to whom the questionnaire was sent have replied either by giving very valuable detailed information or by saying that the state of development of their railways is not such as to justify as yet the installation of such an advanced type of signalling as that which will occupy us in the present report. We wish to express our thanks at this point to the engineers concerned on these different railways for the kindness and readiness with which they have supplied us with the particulars on which our report is based.

## I. — Remote control and operation of points and signals by means of relays.

On single track lines the remote control system has, where used, replaced manual block, electric staff, tablet and token working and on the American Railways manual block and the « Train Order » system.

On double or multiple track lines it has replaced control from a local signal box.

The system has been used to effect economy, to speed up operation and to increase safety where points were formerly hand operated and no interlocking protection existed. On the American Railways operation was speeded up by eliminating train stops to operate hand points.

It is the general intention to extend the system as circumstances warrant. Although the coded relay system has been little used except in America where special conditions exist, this is because a case has not been made out for it except under special circumstances.

The principal advantages, where it has been justified, are saving in operating costs and speeding up operation. In the American case, where points were hand operated and no interlocking protection existed, increased safety was provided in addition to the speeding up of operation.

Except in the larger installations no special maintenance arrangements have been found to be necessary. Regular inspection, overhaul and test of the equipment is required as with other electrical signalling equipment.

It is the general experience that there is no particular difficulty in obtaining suitable staff for the maintenance of this special equipment except where there is a general shortage of skilled labour. Staff are usually suitably trained for the work.

## II. — Electric power signalling installations.

### *Interlocked levers or free push button or switch system.*

The question was asked as to whether, in the case of large electric power signalling

installations, a system using miniature interlocked levers or a system of free push buttons or switches was preferred.

Through free push button and switch systems are being used to an increasing extent it is considered that sufficient working experience has not yet been obtained to say whether such systems or the well tried power signalling systems using miniature interlocked levers would be preferred.

It is common practice of most Railways to make use of selection to reduce the number of levers where the interlocking lever system is used. By this means, using one lever to operate signals controlling several routes, the size of the lever interlocking frame can be restricted, thus meeting one of the objections hitherto raised against the lever interlocking system.

In free push-button or switch systems the Belgian, Danish, French and Portuguese Railways use buttons mounted on a desk separate from the illuminated diagram for the following reasons :—

- (1) ease of mounting and of making any alteration to the desk;
- (2) ease of control of the traffic operations by the signalman, placed at sufficient distance from the diagram.

The Netherlands and Swiss Railways have decided to make an initial application of the arrangement in which the buttons are placed in their geographical positions on the diagram. Norway states that a trial installation of this method will be made there.

In the small installations the Spanish Railways always use the geographical type of panel with buttons mounted in place on it, as this is more easily understood by the signalman.

On the Swedish State Railways only exceptionally are the buttons mounted in their geographical positions on the panel, but it is proposed to adopt this method in future on an increased scale.

So far as the English speaking countries are concerned, at small installations of the

push button or switch systems it is usual to fit the push buttons or switches on a geographical panel. At large installations they are sometimes fitted on a geographical panel and at others on a separate desk panel. At very large interlockings it is sometimes difficult to arrange a geographical panel so that all push buttons or switches can be reached conveniently for operation. In some cases the panel is divided into sections so that the push buttons or switches are all within easy reach. Where this is not practicable they are fitted on a separate desk panel.

It is the intention of the New Zealand Government Railways to mount the buttons on a separate desk in new installations. The Pennsylvania Railroad have a system of free levers using non-interlocked miniature levers, the interlocking being accomplished through relays. This relay interlocking system is somewhat similar in principle to relay interlocking systems using free switches or push buttons. Automatic route setting can, of course, be employed with miniature levers as well as with the push button or switch systems.

The question was asked whether it is possible to make an automatic selection of alternative routes between two points so that the first free route is automatically selected according to the order decided in advance.

Although it is practicable to arrange for automatic selection of two or more possible routes between two points there are only a very few installations incorporating this feature. If the push button system were employed on the Pennsylvania Railroad it would be their intention to arrange to automatically select the preferred route and in case this route was in use the second route would be automatically selected. In cases where the track layout would permit of it, it has to be considered whether the facility would justify the additional complications to the electrical circuits.

With regard to the relative technical advantages of the interlocked lever system

and free push button or switch systems, the S. N. C. F. remarks that use of the latter enables the electric locks used on interlock levers to be dispensed with and that the lock is a somewhat delicate device calling for careful maintenance.

This is not the experience of British Railways who have found that the electric locks which they use are most reliable and give little trouble.

In order to compare the technical advantages of the different systems it is necessary to have had experience in operation over a number of years. A considerable number of installations of the interlocking miniature lever system have been in use on British Railways for many years and have given excellent results. A number of different types of push button and switch systems have recently been installed but it is considered too early to assess the relative technical advantages.

The Pennsylvania Railroad points out that the interlocked lever system involves technical problems in the design and manufacture of the interlocking machine which do not arise with the push button system. On the other hand, whilst the push button system has less mechanism than the interlocking machine, it has two to three times the number of controlling relays and electrical circuits.

The South African Railways consider that as the circuits of the interlocked lever system are simple and the apparatus straight forward it is easier to alter, both from the Drawing Office and installation point of view. Also special apparatus must be used for relay interlocking systems.

On the other hand some Railways feel that there is a real value in substituting relays used in a system of relay interlocking for the electric locks and mechanical interlocking associated with an interlocked lever system and that the work of the fitter would be completely obviated in the future.

With regard to the question as to whether greater technical knowledge is necessary for the staff maintaining push

button or switch systems only those Railways which have had considerable experience of such systems are able to provide replies.

It is not considered that greater technical knowledge is required on the part of the maintenance staff for maintaining free push button or switch systems than for interlocked lever systems but proper training of the staff is necessary owing to the much larger number of circuits and relays associated with push button and switch systems.

The general opinion is that there is little difference in the overall prime cost of the different systems or in the cost of day to day maintenance. The number of relays requiring periodical overhaul, however, is considerably greater in the case of the push button and switch systems.

### III. — Automatic signalling. Track circuits.

*Using permanent current or coded current.*

Apart from the American Railways where coded current track circuits are used fairly extensively, France is the only country which reports using coded current track circuits though the Italian State Railways are employing them with the automatic signalling now being installed on the Rome-Naples and Florence-Bologna lines and some experimental sections have been installed for trial on the British and New Zealand Railways.

The replies received concerning the maximum length advisable for permanent or coded current track circuits vary to a large extent. This is not surprising as it depends upon the ballast conditions and type of rail fastening, for example screwed to or bolted through the sleepers, and upon the train shunt desired.

The train shunt is governed by the maximum variation in the ballast resistance and by the minimum value to which this falls. Under conditions of maximum ballast resistance the train shunt cannot be higher

than the minimum value to which the ballast resistance falls. The train shunt is therefore not governed by the length of a track circuit alone. Consequently actual train shunts for track circuits of various lengths cannot be given as so much depends upon other factors.

It is fairly general practice to lay down a minimum value below which the train shunt should never fall. On British Railways the minimum allowed for all track circuits is 0.5 ohm except for alternating current track circuits using impedance bonds where it may be allowed to fall to not less than 0.3 ohm. The South African Railways lay down a minimum of 0.5 ohm for all track circuits and the New Zealand Government Railways give values of from 0.3 ohm to 1 ohm with track circuits half a mile long. The Bombay, Baroda and Central India Railways give the shunt obtained with track circuits 546 yards long as between 4 and 8 ohms for direct current. 0.3 ohm for alternating current and 0.2 ohm for alternating current with impedance bonds. The Victorian Railways permit a minimum of 0.1 ohm for direct current track circuits and the Pennsylvania Railroad stipulate that the train shunt for all types of track circuits shall be not less than 0.06 ohm.

According to the opinion of those Railways who either use coded current track circuits or have the matter under consideration, the advantages of this system are chiefly :—

- (a) For sections of equal length the train shunt is greater than with track circuits of other types.
- (b) Conversely for a given shunt value the length of the sections obtainable is greater than with any other system.
- (c) Extraneous or leakage currents are less likely to influence the working.
- (d) The possibility of transmitting several different indications and of controlling the signals without using line wires.
- (e) The possibility of adopting cab

signalling with A.C. coded current track circuits.

The last advantage claimed would depend upon the desire or otherwise to adopt a full cab signalling system. A.C. coded current track circuits would require to be installed continuously over long distances before such a cab signalling system could be introduced.

It would appear from all the replies received that practically speaking no economy is realised by using coded current track circuits. Only the technical advantages set out above are obtained, to compensate in some measure for the greater cost of the coded current equipment.

The possible use of longer track circuits and the saving in line wires may result in economies in certain cases, particularly where some systems of speed signalling are used. The same economy in line wires would not be effected in the case of a simple signalling system such as is used on British Railways.

The general opinion is that there is full confidence in the correct operation of permanent current track circuits and of coded current track circuits both from the point of view of safety and regular operation. In theory, the coded track circuit being less likely to be wrongly affected by foreign currents, there is some increase in safety but appropriate steps are taken with permanent current track circuits to avoid this possibility.

All lines using alternating current track circuits use power from the railway supply through a substation where such a supply is available. In other cases public supplies are used.

It is the general practice where a power supply is readily available, either from the railway supply or from a public supply, to operate direct current track circuits from trickle charged secondary batteries. In the majority of cases, where a power supply is not readily available, direct current track circuits are operated from primary batteries.

On steam lines on British Railways alone there are many thousands of track circuits operated from primary batteries.

The frequencies used for coded track circuits are generally 75, 120 and 180 per minute. The precautions usually taken to prevent the coded current of a track circuit affecting that of the adjoining track circuit are to arrange that the polarity of the coding current is staggered in a similar manner to ordinary alternating current track circuits.

Where the alternating current coded system is used by the Pennsylvania Railroad, lock out protection is provided in which energy from an adjacent track circuit energises the track relay continuously.

On the Italian State Railways arrangements have been made under which a test permanent current is applied to the circuit before the coded current. If a joint breaks down this prevents the former being followed by the latter. In another arrangement the coded circuit replaces the permanent current after the signal concerned has been set to show permanently its most restrictive indication.

For insulating the rail joints most Railways use vulcanised fibre or bakelised cloth plates between the fish plate and the rail, fibre bushes in the bolt holes and fibre plates between the rail ends. British Railways also use an insulated joint known as the « Williams » joint but are now using a solid fish plate made of laminated insulating material. These are also being used by some other Railways.

On some lines metal joints insulated with bakelised fibre are being tried whilst some lines are still using wooden joints or supported joints.

With one or two exceptions the average number of breakdowns of all kinds per signal per year on automatic block installations is less than one. Typical figures are 0.6, 0.5, 0.39, 0.33, 0.21 and 0.15.

This is a remarkable result to be obtained at the present time and with the equipment in question. The Paris Trans-

port Board gives however an altogether exceptional figure of 0.05 failures per signal per year, of which half is due to the components of the track circuit. Each signal is operated about 120 000 times a year.

It is as well to add here that of the total number of cases on the various lines, the number of failures prejudicial to safety is practically negligible.

The very great differences between the replies given to the question as to the average distance between the signals shows that this is dependent on the frequency and speed of the trains and the braking distance required. In considering the re-signalling of a line due consideration should be given to possible future requirements in respect of speed and braking distance.

On lines operated on the automatic block system the signalman in charge of a junction is informed of the direction which an approaching train must take by means of telephone or bell codes given from the previous signal box or by train describers. On multiple track lines where a number of trains may be approaching simultaneously on adjacent track, train describers are necessary.

On certain Railways, such as the British, Danish, Norwegian and Swiss, a train may only pass an automatic signal at danger after receipt of a telephone authorisation from the nearest signal box or station. On the British Railways this is always from the next open signal box ahead and the controlling track circuits are indicated in the signal box.

There are other systems under which a driver is permitted to pass a signal at danger, as follows:—

(a) Automatic signals may be passed at danger under certain rules but controlled signals may only be passed at danger by specific instruction. Automatic signals are distinguished by a letter « A » on the signal. Controlled signals which become automatic when a signal box closes are

indicated by an illuminated letter « A » when working automatically;

(b) Automatic signals which may be passed at danger under certain rules are distinguished by a marker light fixed below the main signal. In most cases the marker is a red light. Where the red marker light is vertically under a red light in the main signal, the meaning is « Stop and Stay » and a driver is not permitted to pass such a signal at danger. Where the red marker light under a red light in the main signal is to one side, the meaning is « Stop and Proceed » and the signal may be passed at danger under the appropriate rules.

#### IV. — Light signalling.

##### *Signalling for direction or speed.*

There are two distinct schools of thought as to the desirability of giving to drivers an indication of the direction in which a train is routed at a diverging junction.

The majority of the railways use a system of speed signalling, some of them giving no indication of direction whilst others combine with their speed signalling some indication of the route to be taken.

This is done in different ways, often by means of a series of conventional rulings combining the ideas of speed and direction in an arbitrary manner. This complicates the reading of the signals.

Other railways, notably the British, do not have speed signalling but use a system of four simple running aspects indicating danger, caution, preliminary caution and clear, with a direction indication at the home signal at a diverging junction.

In colour light signalling territory British Railways arrange that at a diverging junction where the permissible speed on the diverging line is restricted, the home signal is maintained at red until released by the occupation of the approach track circuit. The signal then automatically changes to a proceed aspect, green, double yellow or single yellow according to the signal aspects ahead. The extent to which

the speed of a train is reduced before the home signal assumes a proceed aspect is governed by the length of the approach track circuit.

Flashing lights are not used in main running signals in the following countries : Algeria, Austria, Belgium, Czechoslovakia, France, Great Britain, Hungary, India, Luxemburg, Mozambique, New Zealand, South Africa, Spain, Switzerland and Victoria (Australia).

The Pennsylvania Railroad (North America) report that flashing lights are used only for displaying a « Train Order » signal to convey information to the driver that orders will be delivered. The periodicity of the flashes is approximately 30 per minute.

The Belgian Railways intend to use lights flashing at 60 flashes per minute to control wrong direction movements on electrified lines in order to prevent any confusion, at the entrance to a station where there are four tracks, with the signals controlling adjacent tracks.

The Danish lines use flashing lights in distant signals, with 60 flashes per minute.

In Italy the yellow and green indication at the distant signals is made flashing when the speed limit at the signal in advance is 60 km (37 m.p.h.) instead of 30 km (18 m.p.h.). The periodicity of flashing is 60 per minute, the lamps being fully lighted for 2/3rd and partially lighted for 1/3rd of the time. (The feed to the lamps is never completely interrupted.)

If the variation between the two degrees of illumination is made sufficiently large, the appearance of flashing is quite clearly noticeable.

The Netherlands Railways use a light flashing at 180 to the minute as a calling-on signal, to show that the track ahead is occupied, and one flashing at 75 to the minute for signals which are less than braking distance from the stop signal ahead.

The Norwegian lines use them at 60 flashes per minute for the red lights protecting the entry to stations and

movable bridges. In addition all yellow and green indications in the caution or distant signals are flashing.

In the new signalling in Portugal flashing is being applied in the distant or caution signals.

In Sweden a flashing light is used in the distant or caution signals, both in automatic signalling and at stations. The periodicity is 60 per minute, both for electrically and gas lighted signals.

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The precautions taken by most of the railways to prevent the yellow light being confused with the red, or vice versa, are by ordering to a strict specification and by checking.

The Hungarian, Belgian and Swiss Railways do not use a yellow light singly and the two latter have adopted the following rule :

« A yellow light is never seen by itself but a red light is invariably shown singly. »

This means that in order to avoid confusion between a yellow and a red light, the various combinations of lights are so arranged that yellow is always combined with another yellow or with one or more green lights, while the red indicating « stop » is always seen by itself.

Almost all the railways intend to use colour light signals systematically when lines are electrified. In a few cases semaphore signals may be retained in certain districts where the overhead traction equipment does not interfere too seriously with the view of such signals.

The Pennsylvania Railroad usually support the signals on a catenary structure both overhead and at the side of the tracks. The Spanish National Railways have hitherto used independent supports for the signals but they see no objection to fixing the signals to the traction, standards in the case of new electrifications.

The other railways intend to use independent posts for the signals except in

some cases where a signal gantry would be required advantage may be taken of the catenary structure should this coincide with the signal location.

Some of the advantages of using separate posts are that it is better from the point of view of locating and sighting the signals, vibration of the light beam and the effect of vibration on the lamp filaments are avoided and it is less costly than providing special fittings for the catenary structures.

Of all the railways consulted which possess electrified double track, only the Norwegian uses wrong line signalling in order to allow the traction overhead line to be inspected and overhauled while the track concerned is out of use.

Belgium and Denmark propose to use in future on electrified lines wrong-direction signalling, because of the dense traffic which does not allow maintenance to be carried out during the intervals between trains.

France and Switzerland occasionally consider using a temporary wrong-direction signalling arrangement.

Occasionally a line is signalled for two direction working in order to increase the carrying capacity of the line but this is quite distinct from the question of both-way signalling for the maintenance of catenary lines.

### SUMMARIES.

From the information supplied by the different Railway Administrations the following conclusions may be drawn :

#### **I. — Remote control and operation of points and signals by means of relays.**

1. Except in North America where special conditions obtain in that long lengths of line have been operated on the « Train Order » system, remote control of signalling by means of a coded relay system has not been used to a very large extent.

2. A number of other railways have,

however, used the system to some extent and intend to extend the system as circumstances permit.

3. Where the system has been applied it has replaced manual block on double lines and token working on single lines and in some cases has enabled signal boxes to be dispensed with.

4. The system has been used to effect operating economy, to speed up operation and to increase safety.

5. It seems that the coded relay system could only be applied economically where the signalling controlled is at a considerable distance from the controlling point. The economical distance is generally decided by the cost of the coded relay equipment as against the cost of the number of controlling circuits needed for direct control of each signalling function.

6. No special maintenance arrangements have been found to be necessary and there has been no particular difficulty in obtaining suitable maintenance staff though special training is required.

#### **II. — Electric power signalling installations. — Interlocked levers or free push button or switch systems.**

1. Though free push button and switch systems are being used to an increasing extent it is considered that sufficient working experience has not yet been obtained to say whether such systems or the well-tried power signalling systems using miniature interlocked levers would be preferred.

2. The advantage of the free push button or switch system would seem to lie with the operating rather than the technical side as these systems embody a greater number of complicated circuits than a system of individual interlocked levers.

3. It is not considered that greater technical knowledge is required on the part of the maintenance staff for maintaining free push button or switch systems than

for interlocked lever systems but proper training of the staff is necessary owing to the much larger number of circuits and relays associated with push button and switch systems.

4. There is little difference in the overall prime cost of the different systems or in the cost of day to day maintenance. The number of relays requiring periodical overhaul, however, is considerably greater in the case of the push button and switch systems.

5. It is considered that free push button or switch systems give rise to rather more serious and complicated problems for the traffic department in case of breakdown than with interlocked lever systems. This being so it is necessary to design the system so that a fault can be rectified quickly such as by the use of plug-in relays.

6. Opinions as to whether push buttons or switches should be fitted on a geographical panel or a separate desk panel are divided.

### **III. — Automatic signalling. — Track circuits using permanent current or coded current.**

1. Coded current track circuits are used fairly extensively in North America and to some extent in France and in new installations in Italy. Some experimental sections have been installed on a few railways and the system is under consideration by others.

2. Except where continuous cab signalling is being contemplated, the advantages claimed for the coded current system do not appear to compensate for the increased cost and complication except in special cases.

3. There is full confidence in the correct operation of permanent current track circuits both from the point of safety and regular operation.

4. It is not practicable to say what maximum length of track circuit is advisable

as this depends upon several variable factors such as ballast conditions and type of rail fastenings.

5. The train shunt is governed by the maximum variation in the ballast resistance and by the minimum value to which this falls. Under conditions of maximum ballast resistance the train shunt cannot be higher than the minimum value to which the ballast resistance falls. The train shunt is therefore not governed by the length of a track circuit alone. Consequently actual train shunts for track circuits of various lengths cannot be given as so much depends upon other factors.

6. It is fairly general practice to lay down a minimum value of train shunt below which it should never fall. A different minimum value is usually stipulated for different types of track circuit but except on a few of the railways the lowest figure is 0.15 ohm. It is considered that this value is rather lower than could be desired and consideration should be given to the best means of raising it in order to increase the safety factor.

### **IV. — Light signalling. — Signalling for direction and speed.**

1. The systems of light signaling used by the different railways vary so much and each railway, owing to the amount of signalling already in use, is so committed to its own system that it would not be practicable to adopt a uniform system for all railways even if a common system could be agreed upon.

2. The majority of the railways use a system of speed signalling, some of them giving no indication of direction whilst others combine with their speed signalling some indication of the route to be taken. This is done in different ways, often by means of a series of conventional rulings combining the ideas of speed and direction in an arbitrary manner. This complicates the reading of the signals.

Other railways, notably the British, do

not have speed signalling but use a system of four simple running aspects indicating danger, caution, preliminary caution and clear, with a direction indication at the home signal at a diverging junction.

Some of the advocates of speed signalling not giving any positive indication of the direction to be taken by a train at a diverging junction claim that a reduced speed indication does in fact give an indirect indication of the route set up.

If the signal indication given for a train approaching a junction set for a diverging route can be the same as that given for the straight route, for example with signals ahead of the junction at danger, then this claim cannot be substantiated.

3. The majority opinion is that it is desirable for a driver to know at a junction whether the route which he should take is correctly set up. It is considered sufficient if an indication of a divergence is given at the junction home signal.

4. Although both the multi-lens type and the type of colour light signal with a moving vane with two or three coloured glasses are used to a considerable extent, it is generally considered that the advantage lies with the multi-lens type.

5. With regard to lamp bulbs, the single filament type is preferred as with two filaments, however close together they may be, they cannot both be at the focus of the optical system and the one out of focus gives a reduced visibility which cannot altogether be compensated by increased power. Also both filaments may be disconnected from the supply at the same instant or failure of the second filament may soon follow failure of the first.

6. It is desirable for the lights of controlled signals to be indicated in the signal box and, at least for automatic signals, for the lamp in the red aspect to be proved alight before the next signal in rear can assume a proceed indication.

7. There should be no confusion between red and yellow lights provided that the colours chosen are distinct and the lenses and glasses are obtained to a strict specification within close limits. No objection is therefore seen to the use of a single yellow aspect by itself or a single red aspect by itself.

8. On lines equipped with an overhead electric traction system colour light signals should be used systematically though for economic reasons semaphore signals may be retained in some districts where the overhead traction equipment does not interfere too seriously with the view of such signals.

9. It is better from the point of view of locating and sighting the signals and to avoid vibration of the light beam and damage to lamp filaments to fix the signals on separate posts rather than fix them to the catenary structures.

10. Flashing lights are used by several countries but for different purposes.

## GENERAL.

1. With one or two exceptions the average number of breakdowns of all kinds in automatic signalling sections is less than one per signal per year. This is considered to be a remarkable result with the equipment concerned. The number of failures prejudicial to safety is practically negligible.

2. Automatic signals may be passed at danger under two systems :

(a) only after receipt of a telephone authorisation from a signal box or station and

(b) under certain rules without telephone authorisation, the signals which may be so passed being indicated in some manner such as by a marker light or other sign.

The system requiring authorisation by telephone would seem to be the more desirable where this can be arranged.

## SECTION IV. — General.

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### QUESTION X.

**Drawing up the financial balances regarding passenger and goods services taking into account the prime cost of trains : per category, per line and per type of motive power.**

#### **Principles and methods of calculation,**

by Arne SJÖBERG, M. A.,

Special Reporter.

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The question was dealt with in two reports :

Report (Austria, Belgium and Colony, Bulgaria, Czechoslovakia, France and Colonies, Greece, Hungary, Italy, Luxemburg, Netherlands and Colonies, Poland, Portugal and Colonies, Rumania, Spain, Switzerland, Syria, Turkey and Yugoslavia), by R. DUGAS (see *Bulletin* for June 1950, p. 1217/37);

Report (America (North and South), Burma, China, Denmark, Egypt, Finland, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States, Norway, Pakistan and Sweden), by ARNE SJÖBERG (see *Bulletin* for April 1950, p. 447/1).

The object of the present report is to summarize these reports and give an idea of the tendencies which now appear to make themselves manifest as regards cost calculations and profit and loss statements (financial balances).

As to content this special report has been planned in cooperation with Mr. DUGAS.

#### **General.**

The questionnaire to the various Railways was jointly drawn up by Mr. DUGAS and the reporter and was sent to 108 Railways. Of these, 65 Railways failed to ans-

wer, 30 Railways stated that they did not prepare financial balances for passenger and goods services or that they had nothing of interest to communicate on this question and 4 Railways declared that shortage of staff or prevailing unsettled conditions rendered it impossible for them to answer the questionnaire. Only 9 Railways, which more or less regularly prepare financial balances for passenger and goods services, have supplied answers of real interest for the question under study. Most of the Railways stated their general interest in calculations for cost analysis and cost control. Some also gave information that on special occasions, they made studies of costs and economic results of particular services or regions of their Railway system. However, they did not give any details of the results of these studies.

From the very beginning of the Railways, more or less perfect calculations of average costs have been made. Some Railways also have made calculations of marginal costs for passenger and goods traffic as well as of the profitableness of different classes of traffic (passenger, goods, etc.) and of different lines or regions of a Railway system. The necessity of such cost and profit calculations of various kinds, that give reliable information of what parts

of the Railway production that are unprofitable, have never been greater than in our time. During the last decenniums the business problems of the Railways have become more complex and difficult than before, above all owing to the fact that the monopolistic position of the Railways in the sphere of land transport has gradually been weakened by the fast development of the highway traffic. The earlier, relatively quiet, development of the Railways during their time of monopoly has been followed by a more dynamic development, where the Railways in intense competition with other means of transport have to fight for their traffic. The greater national Railway systems all over the world — most of which are now owned by the State — have reached a size where the usual « penalties for bigness » begin to work in management coordination and selling activities. Or to quote a prominent american Railway officer : « Too frequently business enterprises have become so large and so largely departmentalized by function that responsibility for profit (net income) has become obscured or entirely lost. In many companies, and this is particularly true of railroads, the only man responsible for profit is the president, and he can't be held accountable for net income because he is too far away from the firing line where money is made or lost. Many companies are successfully resorting to the process of decentralization — whereby the business is broken up into as small operable units as possible, each unit being under the jurisdiction of a general manager whose performance is measured solely whether or not he produces a profit. It is almost axiomatic that decentralization results in greater net income or profit, but only, however, if accounting supplies the information needed to control the various segments. The railroads have too long neglected the principle of decentralization in their management structure. » (Vice-President CARMICHAEL, *New York, New Haven and Hartford Railroad*.)

To improve their economic conditions

and their competitive position the Railways all over the world have now — following the example of the manufacturing industries — in varying degrees begun to apply the different tools of modern scientific management, including among other things production planning and control with cost analysis, market analysis, flexible budgeting and standard costs, work simplification and other means of control and reduction of costs as well as more flexible selling methods. The importance of an efficient planning and research department, dealing with cost and market analysis and long-run planning of production, selling and investment, is fully recognized by more progressive Railways, particularly in U. S. A. As an example of a U. S. Railway management's attitude in this respect the following quotation may be given : « No branch of the railroad industry has today a greater opportunity than the accounting department to contribute to the industry's welfare and progress. Not even the Diesel locomotive and centralized traffic control can do more to help the railroads than modern accounting methods. The industry urgently needs accounting departments with the knowledge, skill and ingenuity required to apply to the railroads the new techniques of control which the accounting profession has developed. » (President BARRÈGER of the *Chicago, Indianapolis and Louisville Railroad*.)

#### SUMMARIES.

1. — The use of an efficient system of cost finding is still very limited among the Railways and often merely in an experimental stage.

2. — From the experience already acquired by different Railways it can be concluded that in the present Railway economic situation a workable cost finding system including among other things calculations of marginal and average costs of trains per category, per line and per type of motive power and of financial balances

regarding passenger and goods services and different regions of a Railway system must be considered to be of fundamental importance in attaining efficient and financially sound Railway enterprises.

3. — In broad outline two different systems of cost finding can be distinguished, « the accounting method » and « the alternative budget method ».

The accounting method is primarily based on an analysis of the expenses of a past year, while the alternative budget method involves an estimation of the development of future expenses and revenues.

However one can distinguish different lines of development as regards the accounting method. At one extreme a very schematic cost division between a few service branches and at the other a very detailed accounting analysis of the costs of different categories of trains, traffics, etc. According to the latter very complete variant of the accounting method the calculated costs of the base-year, when applied to future time periods, are readjusted to take into account modifications in the economic conditions, in the traffic characteristics, etc.

In its most advanced form the accounting method, as applied e.g. in France and in Belgium, will therefore give the same results as the alternative budget method.

4. — A general system of cost finding comprises as a basic element calculations of average and marginal costs of different operating services (cost of trains per category, per line and per type of motive power, etc.) and of the various categories of traffic services (costs per passenger carried, per ton forwarded, costs per passenger-kilometre, per ton-kilometre, etc.). With these costs as a basis one can form e.g. the financial balances (profit and loss statements regarding passenger and goods services), which are the main interest of this report.

5. — Profit and loss statements of passenger and goods services are indispensable for attaining a rational business policy of

the Railway enterprise as regards the general level of fares and rates of these two principle classes of traffic. For fixing the individual fares and rates within passenger respectively goods traffic, however, one has to know the appropriate average and marginal costs of traffic.

6. — Profit and loss statements of different classes of traffic are used for establishing « full cost »-prices, which the Railways often apply to postal and military transports, where the payments according to government's order must be fixed on a « cost of service »-basis.

In establishing profit and loss statements of this kind all costs — even the common and constant costs — must be separated between the different classes of traffic.

7. — Profit and loss statements may be prepared for a line or a group of lines of a Railway system. Statements of this kind have been established by various Railways, particularly for secondary lines.

Such statements, that often will be rather arbitrary and conventional as regards calculation methods, are nevertheless of great practical value as a measure of the relative profitability of different lines of a Railway system. Particularly for economically weak lines these statements fulfil an important task in the restraining of business-economically unauthorized claims from different « pressure groups » as regards rates and fares, frequency of trains, etc., on these weak lines.

Statements of different lines, when put together for a sequence of years, are also of great importance in judging the development of expenses and revenues of the different lines and can thus serve as a useful guide in the work of controlling and increasing the efficiency of the enterprise.

8. — As a comprehension of the above may be established that the Railways nowadays more than before must have at their disposal reliable and sufficiently detailed data about costs and revenues of different products, classes of traffic, lines or regions

of the Railway system, etc., in order to be able to perform an economically rational business policy as regards price-fixing and other forms of sale policy, choice of productive resources, production organisation and management efficiency control of selling and production activities.

9. — In developing a national transportation policy by the Government and its different agencies, where the most important problem will be to create an economically rational coordination between the different means of transport, Railways, highways, waterways and airways, it is necessary to

have adequate knowledge of the comparative costs of performing different transportation services, by each of these means of transport.

It is therefore desirable that cost calculations and profit and loss statements (financial balances) of the same general character as those recommended above for the Railways also are introduced for highways, waterways and airways. As to these latter means of transport it is particularly important to have the costs of the permanent way and the terminal facilities clearly and distinctly accounted.

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## QUESTION XI.

# Organisation and development of medical and social services with partnership of the staff in their management,

by Dr. HUYBERECHTS,

Directeur Général adjoint de la Société Nationale des Chemins de fer belges,  
and A. Huys,

Inspecteur en chef à la Direction du Personnel et des Services Sociaux de la Société Nationale des Chemins de fer belges.

### Special Reporters.

The question under discussion was the subject of two reports :

Report (Great Britain and North Ireland, Dominions, Protectorates and Colonies, America (North and South), China, Burma, Egypt, India, Pakistan, Malay States, Iraq and Iran), by P. H. SARMA (See *Bulletin* for May 1950, p. 841);

Report (Austria, Belgium and Colony, Denmark, Spain, Finland, France and Colonies, Greece, Hungary, Italy, Luxemburg, Norway, Netherlands and Colonies, Portugal and Colonies, Sweden, Switzerland, Syria and Turkey), by Dr. A. HUYBERECHTS (See *Bulletin* for June 1950, p. 1255).

A questionnaire drawn up in agreement between the two reporters was sent respectively to 26 and 81 Administrations.

In the one case, 7 detailed replies were received, and in the other 32.

Our thanks are due to those Administrations, who were good enough to reply to these numerous questions on various points, thus enabling the Reporters to draw up the following report.

One of the authors of the present report wishes to address his particular thanks to the French National Railways, who supplied information as complete as it was valuable, in a document whose form and

matter were equally excellent, the precision and suitability of each phrase increasing the value of the information and document.

We must also pay a well deserved tribute to the exceptional state of perfection to which this Administration has carried its social and medical services.

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In reading the replies received from so many Administrations, one is struck by the diversity of the regulations and laws governing the medical-social activities, or in other words, their Social Security and Social Solidarity.

It is rare to find two formulae that are comparable or even approach one another, still less any that are identical.

Sometimes the ordinary laws apply to railway employees, either just as they are, or with certain special clauses; sometimes the Administration has been able to retain the autonomy of its medical social organisation or obtain such autonomy, either by freely deciding what benefits shall be granted, or being under an obligation to supply at least the equivalent point by point or « in globo » of the advantages allowed by the legal regime. In some countries, the legal regime only regulates

part of the activities in question (in such cases, it is usually a question of Social Security) and sometimes there is no social legislation or practically none, at least in so far as the questions with which we are dealing are concerned.

Nevertheless, it can be stated that all the Administrations, who replied to our questionnaire, are concerned to some extent with the health and well-being of their employees, and all have the desire to increase their activities to the extent that their resources as well as local and regional conditions permit.

It is a general rule that the Administrations are concerned with the health of their employees and generally also with that of their families.

All of them also, without exception, and this perhaps is the only point upon which the replies agree, make themselves responsible for any accidents at work or illnesses due to work, and usually bear the entire costs thereof.

The assistance given as regards unemployment benefit, pension — either on retirement or for ill-health — maternity leave, nursing premiums, etc., differ a great deal from country to country, and even on the different railways of a country.

The differences are above all extraordinarily great as soon as one reaches the field of social assistance, the problem of housing, loans, holidays, the organisation of leisure and sports, educational facilities (professional or other), provisioning and canteens, etc.

The same diversity is found when one studies the way in which the medical-social activities are financed. Between the two extremes (the whole burden assumed by the Administration — or the State — or autonomous fund collected and managed by the staff) every intermediate stage can be found.

In the same way the part played by the staff in the management of the medical-social services takes equally different forms, nearly as many as the replies received.

From the case in which the Administration, which supports the whole financial cost, is in practice completely responsible for the management to the mutual control, which in its most perfect form is to be found on the S. N. C. B. (Belgium), one encounters practically all the formulae. There is however a definite tendency to let representatives of the staff take an ever increasing part in the management of such activities, the increase in their rights and authority going hand in hand, as it should, with increased responsibility.

These few considerations and more especially a perusal of the reports, which enabled this special report to be prepared, will enable the reader to understand the extreme complexity of the problems with which we are confronted.

This also explains why it is such a difficult task to submit any summaries, when we know beforehand that the laws, which bind certain Administrations, will make it impossible for them to adopt them.

In such a wide and fluid field, it is impossible to satisfy every opinion.

We have done our best and endeavoured to present honestly and sincerely the fruit of our investigation and our thoughts, and give below the summaries we think will be agreed by a large number of Administrations, or serve as a basis for a fruitful discussion from which more agreeable formulae can be drawn.

### Summaries.

1) The running of the railway medical-social services is a problem of such proportions that many Administrations have still not got beyond the experimental stage, or preliminary gropings.

In many countries, the creation of a so-called « legal » system is obligatory. Certain Railway Administrations, mainly those who have not a very numerous staff and those operating in the colonies, apply entirely the usual legal system. In countries, where the social evolution makes it

possible, the large railway undertakings have been given the power to set up medical-social services outside the usual legal system, so long as the men concerned receive benefits at least equal « in globo » to those provided by the law.

This system is to be recommended because its greater flexibility makes it easier to adapt it to the special requirements and needs of railwaymen. Consequently we think we might suggest that :

« When the legislation of the country does not make it impossible, it is advantageous for the Railway Administrations to organise their own medical-social services. »

2) Some railways have succeeded in setting up an organisation in collaboration with their staff. In some cases, this collaboration is limited, the actual management being left in principal to the employer; on the other hand, certain Railways have organised complete mutual control services. The co-operation of the staff to a greater or lesser degree gives the best results. In fact, if the staff is guaranteed thereby greater generosity in the medical-social aid given, it is assured above all of the absolutely equitable distribution of the benefits. It also makes possible a better grading of the benefits when outside causes, of a financial nature for example, prevent the complete carrying out of a programme which would satisfy all exigencies. The direct participation of the staff, both as regards the sums they pay into the Fund for Social Benefits, and by its share in the management, the Administration and the control of the work, encourage it to share in all the responsibilities. This leads it to take care that the budget is balanced, to see that there are no abuses, and to look for and apply all the means of preserving the physical and moral health of the men and their families. This state of affairs has a very happy repercussion upon the output of the staff and consequently upon the proper management of the railways.

We suggest therefore :

« Where there is complete or limited autonomy, of the medical-social services, it

is advantageous to let the staff share in the management of these services; at the same time as they take over part of the authority, they will assume a corresponding part of the responsibility. »

3) From the purely medical point of view, certain railways themselves run the medical, pharmaceutical, surgical, etc., services. This system is the only one possible in the case of railways in sparsely populated countries, as also for those in unhealthy districts or at a distance from the large towns. Railways in densely populated countries, whilst encouraging to the greatest possible extent the setting up and extension of railway medical services for the financial benefit of the staff, allow them complete freedom of choice in selecting their own doctors, even outside the railway's medical services.

We conclude therefore :

« When a country's medical services are inadequate or non-existent, the Administration concerned should itself organise such services for its employees and their families. »

4) Social services actually speaking only exist on a few Railways. Some of them have a purely patronal organisation of social services.

In addition to the fact that such a system does not encourage the self respect of the employees, it does not give, as in a solidarity system, any rights to the staff and thus the lot of the most unfortunate is often left to the personal conceptions of certain officials.

On the other hand, the unscrupulous may receive more than their share.

We consider that :

« Social services in particular should be organised on solidarity and equality lines. It is desirable that this idea should oust the idea of « assistance ». »

5) a) In the sporting field, the Railways, who encourage and support the staff sporting associations and thus make possible national and even international meetings and tournaments, not only encourage to

a great extent the physical and moral development of their employees, but make possible the formation of solid links of friendship between the men of the same Railway, men of neighbouring Railways and even those of foreign countries, contributing therefore their part to the cause of peace.

In this connection, the efforts and success of U. S. I. C. (International Sporting Union of Railwaymen) should be stressed;

*b)* as regards the other leisure occupations of the staff, although many Railways encourage art, literary, musical, etc., societies amongst the staff, it would be desirable to see some international societies created, such as those realised in the sporting field and by the tourist associations (International Federation of Railwaymen's Tourist Associations);

*c)* the same object should be pursued in the case of the medical services. Medical science as applied to the very special field of the railway, comes up against special problems to be investigated, which concern both the staff and passengers. It would be useful if all could benefit by the experience of each one. It is therefore a source of satisfaction to be able to report the recent creation of the International Union of Railway Medical Services (U. I. M. C.) affiliated to the U. I. C., to which 12 Administrations already belong;

*d)* nearly all the Administrations help the children of their employees, by setting up for their benefit holiday camps, health centres, etc.

Some Administrations have organised the exchange of children either in individual railwaymen's families, or in groups in homes, holiday camps, etc. Such exchanges often lead to friendships being forged between railwaymen of different countries. This practice also greatly encourages understanding between the citizens of different countries.

Consequently we suggest :

« It is desirable that in every field where

it is practicable, contacts and exchanges shall be organised between the employees of the different Railway Administrations. Where they are already in existence (in the medical field: International Union of Railway Medical Services; in the world of sports: International Railwaymen's Sporting Union; in the tourist field: International Federation of Railwaymen's Tourist Associations); such contacts and exchanges should be extended and developed, to include those Administrations which so far have not taken part in them.

6) Professional instruction on the railways often depends upon the general educational possibilities of the country. But all the Railways find it necessary to organise special railway courses themselves. The action of certain Administrations intended to attract the children of their employees to a railway career, by organising special courses for their benefit and giving them priority when they matriculate, appears to be particularly interesting and recommendable: this leads to the creation of railway families particularly attached to their profession. Finally, collaboration between the different railways will bear much fruit, by the intercommunication of programmes, exchanges of teachers and pupils, visits to installations, etc.

Consequently :

« Railway Administrations would find it of value to organise professional instruction, on the one hand, for the children of employees, who wish to follow the same career as their parents, and on the other hand, for employees themselves to enable them to perfect their knowledge of their profession and qualify for higher and better paid posts.

» It is desirable that contacts and exchanges between Railway Administrations, already recommended in other connections, should also take place in the field of professional education. »

## QUESTION XII.

**What must the importance and the prevailing conditions of traffic be, in order that from the economic point of view :**

- a) the construction of a railway line;**
- b) the keeping operating an existing railway line;**

**should be useful ?**

by N. LALONI,  
Special Reporter.

Question XII was dealt with in the two following reports :

Report (Austria, Belgium and Colony, Bulgaria, Czechoslovakia, France and Colonies, Greece, Hungary, Italy, Luxemburg, Netherlands and Colonies, Poland, Portugal and Colonies, Rumania, Spain, Switzerland, Syria and Yugoslavia), by N. LALONI. (See *Bulletin* for June 1950, p. 1371.)

Report (Great Britain, North Ireland, Dominions, Protectorates and Colonies, America (North and South), China, Burma, Costa Rica, Egypt, India, Malayan States, Pakistan, Iraq, Iran), by Sven BOYE. (See *Bulletins* for February 1950, p. 111 and July 1950, p. 1471.)

1. Seen strictly from the point of view of economics, the problem of determining the minimum requisite volume of traffic to warrant the construction of a railway line or the retension of existing lines, arises as a normal consequence of the typical structure of the expenditure for railway operation.

There is no point in dwelling here on the particular character of rail-borne services as, from the start, these have claimed the attention of economists in view of the well known preponderant part played by the fixed portion in the total cost price, which is characteristic of this type of activity.

We would point out that this position arises as a consequence of the very high

initial outlay of capital required for first building and equipment of the lines, to which must further be added the high fixed part which is characteristic of operational costs (apart from passive expenditure, which is incurred by the capital itself).

The bases on which these data are converted into concrete figures vary from one economist to another; they may also vary from one System to another but, in any case those bases which we have just mentioned form the first condition for the operation of a railway, and this condition, from the point of view of economics, is of prime importance. The existence of this condition had been noted right from the inception of rail transport and it will certainly be agreed that it has increased in importance ever since that date.

This position is the result of increases in invested capital (for electrification, better technical equipment of the Systems, mechanisation of marshalling installations, etc.) and this fact together with the increases themselves has warranted the acceptance of a high initial cost varying in direct proportion to the volume of traffic over which the expenditure will be distributed during the coming financial periods. Another influential factor has been the increasing rigidity of railway administration; i. e. : the decreased possibility of action of the various items of operational costs, due to the increased demands of syn-

dicates and of the public as regards the services to be operated, etc.; these conditions which hinder freedom of action might be avoided if the operating body were able to obtain a more favourable combination of the factors governing production.

We see therefore that, apart from State intervention in view of public needs, the structure of railway operational costs and the predominant part played by fixed expenditures limit of themselves the opportuneness of building new railway lines and maintaining in operation existing lines, and it is true to say that these limits of an economic character have at all times been a fact, whatever the condition of the market.

A new line can only have favourable economic prospects when the presumed volume of traffic is such that after covering the expenses of operation proper, it will ensure remuneration in adequate proportion to the capital invested; in other words, there is a minimum level beneath which a new line ceases to offer any advantage from the strictly economical point of view.

There is a minimum limit even in the case of lines already in existence; i.e.: a volume of traffic insufficient to enable the line to meet its own operational costs, let alone remuneration of the capital invested. This possibility should be borne in mind as calculations in this respect, on building of the line, may have been erroneous in that they over-estimated the future development of a particular area as a result of the new line; further, the economic structure and the volume of commercial exchanges of a particular area may change and thereby modify considerably a position which initially appeared favourable. Therefore, the question arising in each of the above hypotheses is whether or not to continue operation of a line which is showing a deficit.

In the above unfavourable hypotheses, every favourable tariff combination or commercial policy will always ultimately bring about a difference between the pos-

sible paying volume of traffic at minimum operating cost, of a given area and the minimum volume of traffic required if that area is not to lose its every advantage from the economic point of view.

An appropriate tariff and commercial policy can better as far as possible the volume of traffic; an efficient technical organisation can reduce the minimum volume of traffic required, but a difference may still occur, and we can state implicitly that such difference has had a determining effect in every case where investigation as to the opportuneness from the economic point of view of building a new line has yielded a negative result in the past, this notwithstanding the fact that, in the case of lines actually built, such economic investigation has not always been favourable.

It is not possible to state for each individual line and for each country as a whole, whether, and if so to what extent, the economic limit for new constructions has been exceeded; however, we have no hesitation in asserting, particularly if we refer to the period in which the construction of the majority of these new lines was undertaken, that often considerations of a strictly economical nature were outweighed by considerations of a political, economical and social character. Further, even the economic previsions cannot always develop as was anticipated at the time the construction of a given line was undertaken.

Therefore, basing ourselves solely on the particular structure of the railway costs, we can take a railway system as a combination of lines, some of which are showing profit in operation, others operating under less favourable conditions while others still are yielding a quite negative return. Seen from this angle, and quite apart from any appreciation as to the level of technical and economical organisation reached, the efficiency of a railway from the economic point of view, appears as being a direct effect of the manner in which lines of varying types are coordinated in order to form the whole system.

It is self-evident that the more or less favourable position of each of these systems is governed predominantly by factors which are foreign to the railway itself; i.e.: principally the level of economic and social development of the country and the area in which the System is in operation and which determine the volume of traffic which may be received on the System under conditions of economy.

The measure in which the less profitable part of a railway System may be supported economically by the remainder of that System depends on a series of factors which vary from case to case.

Of these factors, the most important are the organisational efficiency of the System and to no lesser extent the action of the State in settling financial relations with the operating body — private company, direct administration, etc. — as these relations influence certain items in the cost price of the railways.

The position does in fact vary according to whether, by such agreements, the railway or the State has been made responsible, in one way or another, for expenditure on the capital initially invested.

However, of all these factors, which vary from country to country and from case to case, there is one on which we must dwell with particular insistence, and that is the proportion of good and bad lines, resulting from technical or economic errors or from prevalence given to considerations other than of a strictly economic order, and which makes it possible to compensate the deficits of the latter by the profits of the former.

This is of major importance when, instead of considering, as we have done up to now, an exclusive field, we turn to a competitive field; we find then that certain factors essential to equilibrium fall away and that the railways are then faced with certain alternatives (and for them also at the political level) with regard to the networks with a high percentage of lines showing a deficit; i.e.: the alternatives either of reducing the extent of the net-

work or of protecting the railway activities as a whole (obviously on main lines before secondary lines) or of making the taxpayer support the burden of lines on which the volume of traffic is below the minimum required to make it a paying proposition. Finally, seeing that, inevitably, the types and nature of lines making up a network differ appreciably from system to system, it follows that protective action which is effective in the case of one given railway will not necessarily be sufficient in the case of another railway.

2. Up to this point, we have considered the importance of the structure of costs in determining the minimum traffic from the economic point of view, solely in the case where the railway is alone on the market.

Obviously, this importance increases when we consider a position which is closer to actual fact; i.e.: one in which other means of transport are in competition with the railway.

If we disregard completely any intervention by the State on behalf of one or other means of transport and assume the theoretical functional conditions of an economy governed solely by factors of economical convenience to be operative, certain consequences automatically arise in which the railway operating cost, calculated as above, is compared with the operating cost of another means of transport to the operator thereof. Further, in view of the typical structure of the cost of either rail- or another means of transport and their level at a given time period, such inquiries may serve as a guide in determining the adoption of one or other means of transport in an area hitherto devoid of any means of communication.

Obviously, we must further assume that, as is normal, the full cost of a given means of transport is borne by its respective operating body; i.e.: that there be no substantial difference between the operating expenditure plus social charges for rail- or for road transport organisations.

We have already stated that the fixed coefficient of the cost of rail services is very high and therefore varies greatly from line to line; the reason for this variation is to be found not only in the many technical differences, but also in the diversity of the volume of traffic on each individual line. In a free competitive market, the cost is compared to that involved by a motor transport organisation. However, the latter, even if it does comprise road transport taxes (taxes on fuel, rates, etc.) is more flexible and, in particular, is in more direct proportion to the distances actually covered.

Expenditure for the maintenance of the road is indeed constant in relation to the taxpayer (and in a certain measure is independent of the volume of traffic); however, this constancy is completely lost to the operator and becomes infinitely variable where a tax on fuel is imposed. And this fact remains even if, as a whole, the expenditure is correctly distributed over the various categories of road users, which is not the case everywhere.

A constant charge also occurs where the fiscal department levies taxes on road traffic, but this is not of any appreciable magnitude.

The very difference in the type of control of the movement of the various transport units (regulated in the case of the railways by ground (static) personnel and in the case of road transport solely by the driving personnel) should already give a pointer as to the areas in which either means of transport (road or rail) may be theoretically applied according to the volume of traffic, even if, with regard to railway lines with light traffic, it is possible to adopt frequencies of traffic (central control, for example) which reduce the importance of this factor. However, we must not lose sight of the fact that road transport organisations have greater flexibility and are able to maintain light volumes of traffic through small transport companies (such small companies are in fact in the majority). Where the volume of traffic

under consideration is not great, the above factors may be of sufficient weight to cancel out any advantage from the purely technical point of view (resistance to movement on road and on rail) which may still favour the railway; i.e.: this technical advantage may vary and thus lessen those points in favour of rail transport precisely in that field where rail transport anticipates a large volume of traffic.

However that may be, this is not the first case in which a determined process of production is convenient if it is able to cater for an extensive production, a large number of clients, etc. In every case though, we should consider the field of electric energy which can be produced by large hydraulic power stations, by thermic stations of smaller dimensions, by electro-generator units (which may be as small as desired) in order to avoid the fixed cost of building a large power station and the conduits for carrying the energy produced over a large distance.

Where the operational cost of road transport falls to the level of that for rail transport (considering an average figure for the total network of lines) or, worse still, has dropped beneath the railway level (as has already happened in the case of certain Administrations), the railway concerned will find itself faced with the acute problem of revising its own production efficiency and organisation. At the same time it becomes necessary — and this may be of predominant importance — to determine accurately the volume of the traffic on the System in question, paying particular attention to its distribution over — and concentration on various lines in order to establish on the one hand that part of the System which shows profit returns higher than those of competitive means of transport (if these are operating in complete freedom), and on the other hand, those sections of the network which involve a financial burden on the System as a whole.

In view of the fact that railway tariffs are uniform a situation of this kind can, if the transport market is freely competitive,

have unfavourable consequences for the railway where apportioning the traffic between rail and road is concerned.

However, apart from difficulties of a financial order we must ask ourselves frankly whether it would not be of greater advantage to replace those lines which are running at a deficit by road transport and inquire into the most suitable way of effecting such a turn-over.

A similar inquiry may be made where, in a wider field, in view of present day technical development, question arises of reducing the financial burden on a collectivity of taxpayers incurred in maintaining an efficient system of transportation. This question has indeed arisen as a direct consequence of the worsening of railway financial conditions and of the inquiries both railway undertakings and governments have been compelled to make with a view to finding the most appropriate means for remedying this negative state of affairs.

3. Comparison of the average cost of road motor transport with that which may be taken as an average for railway operation can serve as a fairly accurate « barometer » for gauging the extent of present difficulties.

The careful examination of comparative data with regard to costs of road or rail transport would enable definite conclusions to be drawn as to the economical use of either of these forms of transport.

Unfortunately, as has already been stated in the Report for French-speaking countries, the data received on this subject are very vague and incomplete and do not permit of any general conclusions being drawn. All that can be said, however, is that, on the majority of railway systems, costs are still below those for road transport; this is naturally a most comforting fact, but unfortunately there are wide exceptions, e.g.: Italy, where the situation is entirely in favour of road transport (at least taking into account the most economical vehicles built to date); in any case even if the average cost of a given System is lower on

certain lines with light traffic, it is often higher than that for road transport.

Whatever the present ratio between the costs for rail and for road transport (the majority of divergences in the various countries may be due to the way in which the calculations have been made or to differences in the modalities of State intervention), it would be of great interest to know the various data over the last twenty years by comparing their variation during that period.

Obviously, every technical improvement in one or other means of transport changes their appropriateness for use as determined simply by the ratio of their respective costs.

In this regard, however, we may well ask ourselves in which field progress is operating with greater rapidity.

I believe we shall all agree that, while technical development has not been lacking on the railway, progress has made greater strides in the automobile industry (as it has made still greater strides in the aircraft industry).

On the other hand, we must take into account the diversity in the starting points of the two systems; i.e.: the railway which has been studied and perfected during a hundred years and the automobile which has been used on a wide scale in the economic and industrial field for only twenty years. It should be noted mainly that in the case of railways, the efficiency of any technical improvement is reduced in proportion to the size of the enterprises and their more or less rigid organisation.

Assuming that the prime costs of the rail and road transport may be known, we may deduce the minimum theoretical volume of traffic at which rail transport is of advantage.

The question then arises as to whether these data can be ascertained in respect of the different Systems and the various countries.

However, all generalisations must be limited in scope, as certain particular factors must be taken into consideration:

1<sup>o</sup> where new lines are concerned, each case must be considered individually, if only because, for example, of the varying investments of capital which become necessary, and the consequent varying charges on each transport unit financed by such capitals.

Further, an additional decisive factor is the need for a network of ordinary routes which, in order to be able to carry the required traffic, require yet further labour and new capital.

In addition, decisions have to be made as to whether, for the projected line, new traction and trailer stock is to be built or whether it can be worked with stock which is surplus on other lines; whether or not it can be included in an electrified network which disposes of surplus electrical energy, etc.;

2<sup>o</sup> with regard to existing lines, the problem is more complicated owing to the difficulty in comparing costs of production for road and rail. As regards rail services, the burden on operational costs of the expenditure due to invested capital — and more generally fiscal, social and syndicate charges — varies from system to system. As to road services, there is variation in the fiscal policy adopted by the State on road transport operation either for public finance or simply in compensation of expenditure in maintaining the road network, etc. Further, there are appreciable differences in both the nature and effects of State intervention in each individual country so that the volume of rail traffic, and its corresponding operational cost, is variously affected in each country by the intervention of the State in the road transport market.

Disregarding the other secondary factors which likewise cause divergences between the various countries and thus modify the bases of comparison (rates of interest, levels of salaries, organisation of services, etc.), we regret to be unable to supply, for each country, data concerning :

a) the comparison between prime costs of transport by rail and by road;

b) the comparison between the fixed and variable parts of which each of these costs is made up.

The data must be available in order to be able to form an accurate judgement as to the respective place and the advantages of each of the two forms of transport in the countries consulted.

However, the results of the inquiry made on this point, while producing a large amount of information, are not sufficient to enable « quantitative » conclusions to be arrived at, much less any accurate judgement as to the maximum and minimum limits of the volume of railway traffic warranting the construction of new lines or the retention of existing lines.

Comparison of accurate data (even if such data were subject to the reservations usual in this kind of inquiry) for each country, had it been possible to obtain such data, would have brought forth some concrete factor enabling a general picture to be drawn of the present state of economy of railway operation and of the minimum volume of traffic requisite in order to maintain normal economic conditions. And it is precisely on this point of the inquiry that information is lacking.

Data is likewise lacking in respect of new constructions even though these are of practical interest for those areas in respect of which a new plan of economic and social development is under consideration.

On the other hand, if we consider the very small number of projects and the very limited extension of the lines therein projected, we may state that the age of new railway constructions is closed, as will indeed be shown further in this report.

The replies in general to the various questions bring to light some notable facts regarding the « conditions » which have to be taken into consideration when examining the problem as to whether a line shall be retained or a new one built; and these replies, further, are sufficiently precise to give an accurate idea as to the particular manner in which each individual country

regards the problem of replacing those lines of its railway network which are running at a deficit by road transport services.

On the other hand, we must repeat here what we have already stated in our Report for the French-speaking countries, i.e.: that the Reporter has been unable to give *a*) any information as to the percentage, in the various countries, of lines whose retention is no longer warranted from the economic point of view, and *b*) any indications as to those sections of the Systems which it may be required to maintain in operation for general or political reasons.

In view of the fundamental importance of this problem and its consequences as regards placing railway finances on a sounder basis, it would appear most useful to draw the attention of the economists and the various Railway Administrations thereto.

Similarly, we are of the opinion that the inquiry should be carried forward, not only in order to answer the question: « What is the volume of traffic? », regarding which it would be very ill-advised to draw any conclusions today, but also with a view to going deeply into each of the individual problems, of a technical, economical, statistical character with which the present inquiry is concerned.

4. In this connection, the first condition which arises to the mind of the observer is that the inquiry should bear on the solvency in operation of each section of line, of each individual line, etc., making up the complete System and this requires data as to the volume of traffic on each line and the characteristic concentration of total traffic.

Having thus established the distribution of traffic, it will then be necessary to apportion, even approximately, the total operational expenditure between the various lines under consideration so as to obtain a series of « balances per line » and thus to be able to place on one or other line or group of lines the responsibility for a given deficit.

Some Administrations have, in a limited measure, investigated, from the economic point of view, the usefulness of retaining one or other line in operation, but no Railway Administration has to date made any complete inquiry of this kind. The very methods employed and the units of mensuration used in the statistics are different.

Only a thorough inquiry can enable an accurate judgement to be made regarding the economic advantage of given rail services as compared with competitive road services; and allow the general problem of the indispensability, from the social point of view, of lower category lines to be seen in its true light.

If general conditions, which can only be appraised on the political level, show that the maintaining in operation of a line in deficit is of general interest to the nation, the railway will then be in a position to couch in more precise terms the problem of defending railway activities, and constrain the Governments to accept their responsibility in pursuing a present policy which may well lead to unjustifiably high social costs.

The inquiry as regards lines with an insufficient volume of traffic undoubtedly brings to the fore the problem of the need for reducing to a minimum the social costs of railways; however, apart from this, the same question arises out of the deficits shown by nearly every Railway Administration. It is for this reason that some of the questions asked related to the present economic position of these railways.

In general, it has been stated that the various measures actually taken as regards road competition are insufficient and that the railways, for various reasons, are unable to hold their own against road competition. The first of the reasons for this is the difference in the social charges as compared with the road.

Further, it is a recognised fact that the financial position of railways worsened after the war, which has given still greater importance to the problem of lines running at a deficit.

5. To establish which are the lines which have an insufficient volume of traffic and to show the influence of such lines on the general budget balance, is certainly a long way from proposing the cancellation of such lines. A decision of this kind must take into account not only the general advantages enjoyed due to the existence of certain lines, but also considerations regarding their possible convenience for working the network of main lines as a whole. In every case then, it is important to carry the inquiry beyond the financial budget pure and simple of a particular line, and to consider :

1<sup>o</sup> the nature of the traffic using the line;

2<sup>o</sup> the economical and technical relation between the lines with a low volume of traffic and those of the main System, bearing in mind that, with regard to the latter, the former represent as many channels for the arrival of traffic.

1) As regards the nature of the traffic, it may be stated that the position of a line with a low volume of traffic varies appreciably according to whether the traffic is evenly distributed in time or concentrated at various periods of the year, month or week. Attention must therefore be directed on the concentration of traffic and its fluctuations on each line; to this end, appropriate statistics should be kept. In this connection, it should be noted that the railways, in view of the nature of their costs, must be able to count on as stable a volume of traffic as possible; however, it is also true that heavily concentrated traffic though not very large in yearly volume may compel the railway to have recourse to road transport which will be the only way for it to meet its obligations.

Apart from this, the concentration of traffic may automatically affect the railway costs without it always being possible to say whether such modification will be favourable or unfavourable. Consequently, even if it were possible to indicate by one single figure the minimum volume of traffic

requisite for profitable operation of a railway, the different concentration of traffic would be likely to modify this figure to an appreciable degree.

2) Next should be considered the various factors in favour of assigning a technical or economic function to each line, in respect to the System considered in its entirety. Among the technical reasons put forward in this regard is the necessity for making use of secondary lines in case of exceptionally heavy traffic on the main lines, disturbance of normal routes, etc.

Where such a series of circumstances arises, the expenditure involved in retaining in operation lines having these characteristics is strictly bound up with the total expenditure for the main System.

However, financial considerations may prove to be still more important than technical factors, and may be such as to have a decisive effect even from the sole point of view of the economic usefulness of railways. In other words, it may be wondered whether the relation between the volume of traffic on lines running at a deficit and that on the other lines (in so far as the former serve as channels for the flow of traffic onto the main lines) is not such as to modify the judgement which otherwise might be arrived at regarding the appositeness of retaining secondary lines in operation (the same may likewise be said of new constructions). This is a question of great importance, by reason of the weight which it takes on in many specific cases. In view of this, a further inquiry becomes advisable, bearing in mind the two following aspects :

a) the actual nature of the traffic on secondary lines;

b) the possible organisation of the service which might eventually be called on to replace rail services, as such organisation may avoid losses of traffic on the main railway System.

With regard to point a), we will limit ourselves to pointing out that it is only

if a line can count on a given volume of traffic, and this traffic is of a local nature, that it would be useful to establish a separate budget as this would make it easier to decide what action should be taken in future in respect of that line.

The other case, point *b*), is more complicated; i.e.: where the same (or a lesser) volume of traffic (gauged according to the pro rata of the given line, section, etc.) is long distance traffic. A line of this kind should be considered as a line of penetration and the traffic using it will therefore be of greater importance than in the first case; such traffic must obviously be taken into account, as it might be wholly or partly lost if the line were closed. This point, among the many uncertainties relevant in the problem, seems to us to be the most important owing to the difficulty of carrying the statistical inquiry beyond ascertaining the volume of traffic relating to a particular section in order to find out the nature and quality of the said traffic and to determine the proportion of it which affects the main railway System and which might be lost if appropriate measures were not taken to avoid this danger.

We may therefore stress the decisive interest of all those problems relating to the inquiries regarding the possible consequence which the cancelling of the secondary lines might have on the main network. But, as the replies have confirmed, all generalisations in this respect are dangerous as the opinions formed are no doubt influenced by the situation of each railway System and by the combined effect on each of these Systems of the lines showing a profit and those running at a deficit.

The problem in this case is one of valuation based on the comparison between, on the one hand, the economy which can be realised by the closing of a line and, on the other by the possible loss of traffic, in respect of the main railway System.

Obviously, this comparison will be influenced by the place allotted to the services replacing rail transport [point *b*]. In this connection, it should be pointed

out that there is an almost general conviction that the consequent loss of traffic to the main railway System might be reduced by some appropriate economic convention, it is in fact recognised that the railways must not disregard road transport as a substitute for lines which are closed and that, on the contrary, such services should be worked under the control of the railway.

A further problem arises at this stage, i.e.: how shall this control over road transport replacing closed secondary lines be exercised: *a*) by direct operation, *b*) by operation being placed in the hands of private enterprise or *c*) by companies linked financially with the railway?

The solution to this problem differs according: *a*) to the standard of organisation reached by each individual System, *b*) whether such private companies exist or not and *c*) whether preference is given by a country to private or public enterprise. However, at this point should be noted the relation existing between the above-mentioned control, whatever form it may take, and the coordination policy. Each of these proposals does in fact arise out of evident diffidence of the transport coordination policy which normally should be followed where the participation of the Railway Administration is lacking.

But in making a decision regarding the services which are to replace closed railway lines, another factor must be taken into account.

Experience has shown that everywhere railway lines running at a deficit have been closed, resistance on the part of the population concerned has been encountered. And so the question arises as to whether these obstacles would be reduced if the road transport services concerned were run by the railways themselves, which would assume the same transport obligations and the same working conditions, etc.

We feel that at least in this way resistance might possibly be more easily overcome. However, certain replies received mention difficulties regarding goods traffic for which

a problem of transhipment arises in every case. However, it is clear that even this factor, while it is certainly negative, must only be taken into account in so far as it influences the decision; it is not of sufficient importance to decide the problem of

Among the various factors which may help in overcoming the above-mentioned obstacles, there is no doubt that the tariff factor is the most decisive.

Would it then be indicated in such a case for the organisation operating the road transport, which replaces the closed railway lines, to apply the same tariff as the main railway system, for it is precisely the loss of this tariff which the circuit fears when a line is closed. The replies received express doubts on this point and stress principally the differences in the relative costs of the two forms of transport. Possibly this is an indisputable fact, but our personal opinion is that numerous cases may occur in which the advantage of transport at lower cost — we refer here to lines with a low volume of traffic through the use of road transport — might be decisive, even if, as a consequence, it was found that the tariff did not completely cover the operator's expenditure. Where the financial position of certain lines is so unfavourable, the operator may thus be able to realise a profit by avoiding the higher expenditure involved in the operation of a railway line. The financial department of the State would also reap benefit therefrom as, one way or another, it has to subsidise the railway.

We believe, for instance that in Italy, cases of the kind mentioned above are numerous and the Italian State Railways would be glad to close many lines with a very low volume of traffic, even if they were obliged to apply their own tariffs to

6. Having considered the purely economical factors which restrain the closing of lines running at a deficit (because of the low volume of traffic), we will mention in passing those of a different nature which

may modify these economical factors; i.e.: considerations appertaining to politics and general economy.

All the railways consulted have stressed these considerations, and it is for this reason that their replies reflect a very low expectancy with regard to the economic results which may be anticipated due to the elimination of the negative part of the railway network. We are of the opinion that a thorough inquiry on this point should be undertaken.

There is no point in stressing here the wide difference between political considerations and those already mentioned which restrain the complete suppression of the railway lines running at a deficit. For, taking the limits in which the purely economic factors of the second category (other than political factors) operate, we find that we are concerned with a cost, for which the Railway Administration must naturally assume responsibility. On the other hand, where extra-economic considerations prevail, the railway is burdened with a cost, for which the State financial department must assume responsibility one way or another; and even when a railway system is operated by direct State administration, it is advisable for this cost — which is of a political nature — to be indicated separately in order to obtain the desired clarity in the financial and economic results of the operation of the railway.

The inquiry, however, must not be limited to obtaining this desired clarification. Even if it is the duty of the political power to ascertain the existence and evaluate the exigencies of an extra-economic order which influence a decision of this kind, our task here is to investigate the validity of the said exigencies and the results consequent on their being accepted. Whomsoever is concerned with problems relating to transport is aware of the great uncertainty caused by the continued interference of factors of a public order in the economical problem of rail transport: he also knows how difficult it is to establish

the extent to which such factors shall be allowed to prevail over strictly economical considerations. However, it is probably more difficult still to decide whether any concrete relation exists between the public interests to be served and the costs to be met (in any one of the various forms possible). On the other hand, it cannot generally be stated with any accuracy whether the profit to be anticipated from a general closing of all the lines of a System which are running at a deficit (likely to bring back economic efficiency to a railway network) will, in itself, be either decisive or of moderate efficacy with regard to the grave position in which railways find themselves today. A judgement on this point can, in fact, only be formed by taking into account the relation, in respect of each System, between the whole network of main lines and the lines with a low volume of traffic. Account must likewise be taken of the ratio between the average costs of railway operation on the one hand and those of competitive transports systems on the other. Consequently, it is not possible to state with precision how far this measure is decisive and further what may be achieved as a possible defence of the railways, if such defence is left solely to the effect of the economic factors.

However, it is a fact that certain factors of a subversive nature are to be feared, i.e.:

1<sup>o</sup> the possibility of a protective policy in favour of the railway might lead to the problem of substituting road transport for line showing a deficit being neglected;

2<sup>o</sup> a policy of substitution might be hampered by opposition on the part of the various populations concerned. We may therefore find ourselves faced with both inside opposition, from the railway Administrations themselves, and outside opposition in the form of local pressure on the political plane. This is indeed what has taken place, to a more or less large extent in those countries where, in these latter years, large scale reconstruction of war damaged lines has had to be undertaken, and this is of special significance.

The above notwithstanding, we would like to stress that it is essential that no considerations aiming at obtaining general advantages can dispense from introducing in the transport services such ameliorations as the present standards of technical knowledge allow.

This question arises because, whatever the agreements arrived at regarding an intervention in order to reach certain social or general aims, etc., it is not certain that all this must be achieved by employing one given form of transport and thereby possibly not using that form of transport which, under the same conditions, would be of the greatest advantage economically.

There then remains the problem of the best choice and user of the different means of transport according to the field of activity in which each has its best chance of success.

In these conditions, the question becomes one of determining the type of organisation to be given to the most economical means of transport in order to be able at the same time to guarantee in no uncertain measure that the aims desired shall be attained. This is a solution which may entail restrictive intervention by private enterprise, together with — where necessary — subsidies, reimbursements, etc.

A problem of this kind may seem simple in itself, but it must be admitted that it will become more complicated due to the fundamental fact that, in respect of a railway, operation and tariff policy are generally affected by considerations of a public order while road transport, entrusted to private enterprise, is operated solely according to private directives.

The ultimate result is that the desire of the users to retain the profit accruing from the operation of a railway line often forms the main obstacle to the substitution of road- for rail transport, even when such action would prove to be economical. State intervention as regards the transport rates therefore becomes the first obstacle which urges the public to demand transport

by rail, even when it would thereby be used beyond its normal field of activity. Where this occurs, the result is higher social charges than those in respect of road transport; there is no point, in this connection, in stressing the increased financial charges which this certainly places upon the public.

The financial charges incurred, in such a case, in ensuring the efficient operation of a System, which is running at a deficit, are greater than the benefits which the public can derive therefrom and we can even observe a clear loss from the social point of view.

Briefly then, examination of every problem of this kind must disregard :

— tariff considerations (particularly where tariffs are affected in a large measure by factors of a political order), and

— the advantages which a given number of users may derive from the fact that one of the competing systems is compelled to operate at a figure beneath the normal cost or, at tariffs which, due to their uniformity, may be at a lower level in one area solely because the railways are able to compensate differences by lines in another area which are showing a profit, or which benefit in general from State subsidy.

It is easy to conclude herefrom that endeavour must be made to ensure reaching these objectives, of a public order, in those cases and to the extent they are deemed indispensable by the public authorities, on the condition, however, that the cost involved be reduced to a minimum by using the most economical means. This field will be found to be fruitful as regards inquiries and practical application, provided that it is possible to overcome the limitations resulting from the differences in operation and the various oppositions which arise mainly out of the tariff policy and the comparisons, which the user is wont to make regarding the transport market.

7. Obviously, before coming to the problem of substituting road for rail transport, we must first ascertain whether it is

possible to ameliorate the position of those lines showing a deficit. The replies received on this subject show that, generally speaking, there is a current of optimism regarding the possibility of effecting technical and organisational improvements through the use of appropriate means of traction and the adoption of administrative systems differing from those in force on the System as a whole.

With further regard to expenditure, it should be pointed out in addition that, as might logically be expected, there is no great confidence, generally, in the abandoning of one only of the two services (passenger or goods) for the simple reason that the fixed costs still continue to occupy a preponderant position in the operational expenditure. However that may be, passenger services seem most likely to be the first to be replaced by road transport. The main reason for this resides in the fact that goods services require transhipment (whomsoever the secondary line may be operated by) which is always an obstacle and likely to increase the danger of losing this branch of traffic.

With regard to receipts, this question becomes a decisive one, where an adequate tariff policy, which detracts from the ruling of uniform tariffs as applied to the System as a whole, is likely to reduce the deficit of a group of lines with a low volume of traffic.

Here, however, other possibilities are to be feared. For even if it is correct that on these latter lines the cost per unit of traffic is higher, an increase of the tariffs would, in view of the competitive road transport services, likewise increase the risk of a loss of traffic on these lines.

On the other hand, the adoption of varying tariffs for each line is not acceptable from the point of view of national economy, as this would cancel out the advantage which the railways have so far enjoyed due to the uniformity of their tariffs. As it happens, the replies received have not omitted to stress both these aspects of the problem.

With further regard to the amelioration of the conditions of lines with a low volume of traffic (be they either a part of the whole network of the System or, as is sometimes the case, independent economic units) the further question arises as to whether they should be granted a different economic and operational organisation. The history of railways in nearly every country shows that reorganisation and amalgamation of railways has always been practised; however, in view of the universal position of railways today, very little benefit can be expected from measures of this kind. Opinions on this point, as stated in the replies received, differ very widely indeed; on the one hand, there is a trend towards possibly centralising the whole System (under the control of the large railway Companies and Administrations) and on the other, a diametrically opposed tendency according to which certain secondary lines, of those at present operated by large railway organisations, could profitably be handed over to private enterprise.

These considerations lead one to believe that solutions might be found in accordance with the different *de facto* situation in each country and principally in accordance with the different economic and political conceptions which may play a leading part in a problem of this kind.

After having examined, at rather great length, the limits in which railway methods may be used in respect of lines already in existence, we shall now cast a brief glance at these same limits with regard this time to new constructions.

The expediency of using railway services rather than road services may be expressed in terms of minimum volume of traffic; in actual fact, however, there are two factors on which such expediency may be based, i.e.: new lines under consideration and secondly lines already in existence. (For the sake of brevity, we will refrain here from mentioning other factors arising from comparison with other systems of transport. In addition, with regard to road transport,

we should consider separately various assumptions according to whether the existing network of roads is sufficient or whether, in view of a given anticipated volume of traffic, new roads — for either common or specialised user, shall have to be built.)

The second factor, concerning existing lines, corresponds to a more moderate volume of traffic. In order to decide on the retention in operation of a railway undertaking, it is sufficient if the receipts cover solely the cost price which will have been calculated disregarding the initial capital or rather that part of the said capital which it would be impossible to recuperate were the line to be abandoned.

Once a difference is thus established between the two minimum values, the sole fact that a question now arises with a view to maintaining the present mileage of the railways in its entirety (due to the fact that more or less extensive sections of these railways have fallen below the limits in which road transport may be used) is proof that the question of new constructions is no longer of interest today.

It may therefore be stated affirmatively that the era of new railway constructions is passed, which means implicitly that comparison of the limits of usefulness is unfavourable to the further extension of railway Systems.

The considerations already contained in this Report (first costs for initial investment which weigh heavily on the costs of railways) show with sufficient clarity that any trend towards intensifying existing Systems would only be justified if, at the same time, appreciable economic development occurred independent of the traffic already carried by rail. (In this regard, economic development of rail connections, if it took place, would mean an increase in traffic in respect of which recourse should be had to those already known technical methods able to cope with a more intense traffic.) In other words, bearing in mind the present development of rail

transport, existing lines are now more than sufficient to cope with an advanced plan of regular communications. Further, due to the impulse which rail communications have no doubt given to economic development, it is very difficult to discover any areas likely to give further economic development in the future and which are not already served by rail transport.

Since when a new means of transport has appeared on the market, it should be noted that, apart from the above-mentioned factors, which tend to limit the Systems, another specific factor has arisen, and that is: the possibility of having recourse to road transport, particularly in those areas where there are roads, which in that case only need to be improved.

Briefly, seeing that railway communications exist for relations having an important economic movement, it is difficult to imagine that any subsequent occasions may arise which will allow the railways to take a further step forward in under-developed areas. In addition, it is hardly probable that there will be any likelihood, in areas of this kind, of economic possibilities favourable to the establishment of new railway communications.

However, special mention must be made of the so-called depressed areas, the development of which is being studied (the South of Italy for instance). It cannot be stated with absolute certainty that there is no room in these areas for future development of the railway network. On the other hand, it is difficult to foresee any rapid amelioration in the economic position such as would immediately render the construction of new railways lines a profitable undertaking. In any case, it would be a mistake to make such economic development conditional upon the extension and amplification of railway services; for in view of, on the one hand, the characteristics of the costs of rail- and road transport and, on the other, the slowness (in addition to the uncertainty) of economic progress in the depressed areas, road transport, at least in the initial stages, is the most likely

to prove economical. This argument is not only true in theory, for in actual fact, it was only last year (and this is borne out by authoritative sources) that the programme for the development of Southern Italy provided for the extension of the railway network on the pretext that rail transport was a « guide » towards the economic development of these areas.

This view, however, was not shared by the majority of experts who expressed the opinion that road transport was better adapted to function as a « guide » by reason of the fact that its prime cost was in more direct proportion to the volume of traffic concerned and that it was not burdened either with heavy fixed costs or with costs of construction and operation. It is of moment to add here that it is only when the development of the areas in question has reached a level likely to warrant a railway System (and only in respect of those areas in which such progress is realised) that the construction of a new railway line can be considered at a second stage of development. As for the first stage, present transport technique is able to bring about the preliminary conditions requisite for the development of general economic activities by using means (road transport) which are more economical and have a lower level of social charges.

All that would then remain to be done would be to organise these road transport services with a view to reaching these political, social and general development aims, etc. (which, traditionally, fall to the railway). In particular, it would be necessary to surmount the difficulties and obstacles which, as has already been stated, occur with road transport when it is operated, as is generally the case, by private enterprise.

The above considerations are not in contradiction with the replies received from the few Railway Administrations with regard to new constructions, either projected or building. In any case, the constructions in question are not of a size which would bring us to modify our stated

opinion, viz.: that the era of new constructions should henceforth be considered as closed. Most of these constructions are of moderate proportions either as regards actual extension or the objectives they are intended to reach.

The question is more one of rectifications or improvements to be made to existing Systems rather than new constructions. In some cases only where new constructions (most of which are only projected) can truly be spoken of, new lines are justified by reasons of a geographical, climatic, etc., order. It is superfluous to stress that the problem of choosing between the two methods of transport only occurs where either of the two methods can be used.

This, however, is not true for instance in northern countries, where road transport cannot be operated during certain periods of the year. (It is in Norway and Finland that the most important projected new railway constructions are under consideration.)

Some of the countries to which we sent our questionnaire and which were able to reply thereto, are also considering the building of occasional short sections of line for economic reasons such as, for example, the working of a mining area, the agricultural development of a given region, etc. But these are lines of no great length as compared with existing lines; further, in view of the high anticipated volume of traffic, these regions represent a possible source of profit for a railway line.

It is only in countries of the first kind (having necessities of a climatic order, etc.) that considerations of public interest, similar to those which, in years gone by, decided the building of certain lines, still predominate.

With regard to the other countries, however, present transport technique is continually offering alternative solutions based pure and simply on the preliminary valuation of the volume of traffic which it is possible to anticipate. And this is the point where rail transport has lost its for-

mer characteristic quality of being the sole means of transport capable of ensuring those traditional aims which have always been attributed to an efficient and well organised plan of national communications.

### Summaries.

In concluding this Report, the following questions arise :

Are the replies received sufficient to enable satisfactory conclusions to be drawn?

Unlike the numerous technical problems which do permit of actual « conclusions » being reached, the possibility of reaching such conclusions in regard to economic problems is very reduced; further, there would be no point in stressing here the difficulties encountered in the economic field. It is particularly difficult to reach « true » conclusions on a problem such as the one we have just examined. This problem, of all those arising regarding transport economy, is probably the most complex and includes inquiry into the economic field of use of the various means of transport; such inquiry is further complicated by interference of extra-economic considerations.

For these reasons, this Report instead of following a logical sequence of comments on and deductions from replies received, has been drawn up in the form of an analytical study intended to serve as a basis for discussion of the question.

However, under the heading « Summaries », we would like to set forth certain points on which the reports from the various groups of countries agree, thereby at the same time forming a summary of the remarks of practical value contained in the above Report.

1) Generally speaking, the various Systems do not keep systematic statistics for each individual line, showing traffic and budget. For this reason, it has not been possible to ascertain the proportion of lines showing a deficit as compared with each System as a whole.

2) No System gives the minimum volume of traffic, requisite from the economic point of view, for retaining a line in operation or for constructing a new line.

3) The problem of lines showing a deficit has become of greater moment since the last war, due to the worsening financial position of the various railway Systems.

In this regard, the measures taken to combat road competition, particularly from the point of view of social charges, are notably inadequate.

4) The various railway Systems are of the opinion that a specialised policy of increased rates and fares with regard to lines showing a deficit would not better their economic position, and in any case such a solution would be difficult to accept from the general point of view.

5) Amelioration of the economic position of lines showing a deficit may be obtained by using light stock and by special technical organisation.

6) Most railway Systems have already met with the problem of substitution of road transport for rail transport, and they are of the opinion that in future this problem will have to be studied more closely than hitherto.

7) The large majority of railway Systems stress the wide political and social consequences, which may arise from the closing of a line which is running at a deficit. However, passenger rail services are those more easily replaced by road services.

On the other hand, the influence of the closing of a line on the technical and economic operation of the railway System as a whole, must not be disregarded.

8) The railway Systems agree unanimously that the road traffic resulting from the closing of a line which was running at a deficit must be operated, or at least controlled, by the railway Companies. However, the general view is that rail tariffs should not be applied to road transport.

9) In general, the railway Systems are not building any new lines, except for certain limited cases where a line is of technical interest and of reduced length or where it is justified by particular geographical or economic conditions.

10) Even in the case of areas which are at present in active development, the actual standard of technique requires a new line to be built only after the various possibilities of the other methods of transport have been thoroughly examined, profitable returns being the decisive factor governing the final choice.

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## SECTION V. — Light Railways and Colonial Railways.

[ 625 .614 & 656 .27 ]

### QUESTION XIII.

## Modernisation of the maintenance methods of the permanent way on the light railways,

by L. RIPERT,  
Special Reporter.

This question was dealt with in the two following reports :

Report (Austria, Belgium and Colony, Bulgaria, Denmark, Spain, Finland, France and Overseas Territories, Greece, Hungary, Italy, Luxemburg, Norway, Netherlands and Colonies, Poland, Portugal and Colonies, Rumania, Sweden, Switzerland, Syria, Czechoslovakia, Turkey and Jugoslavia), by L. RIPERT (See *Bulletin* for May 1950, p. 877);

Report (America (North and South), Burma, China, Egypt, Great Britain and North Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan), by J. R. FARQUHARSON (See *Bulletin* for May 1950, p. 1069).

The object of the present report is to sum up these reports and present the summaries which can be drawn from them. These are concerned with the less important lines of the main line railway companies and those of companies operating secondary railways.

Some of the characteristics of these lines (of a total length of about 100 000 km [62 000 miles]) operated by 39 Administrations, who replied to the questionnaire, are given below :

— about 2/3rds of them are standard gauge or wide gauge lines; about 1/3rd are narrow gauge lines;

- the maximum weights per axle are generally about 15 to 18 t in the case of standard gauge lines and 10 t in the case of narrow gauge lines, but vary within wide limits (from 6 to 23 t and exceptionally 36 t);
- the maximum speeds of the trains vary between 25 and 90 km/h. (15 to 55 miles) in the case of standard gauge lines and 25 to 60 km/h. (15 to 38 miles) in the case of narrow gauge lines;
- passenger and goods services are worked on 87 % of the total length of such lines.

### I. Staff : Modernisation of the organisation of the gangs.

#### a) *Composition of the gangs.*

1. On most systems the maintenance staff is divided up into small gangs of 3 to 6 men, sometimes more, responsible for sections 6 to 14 km (4 to 9 miles) long; the gangs are often increased when extensive operations are being carried out.

On the lines of 15 Administrations, the staff has been grouped into long distance gangs. The length of the sections for which they are responsible varies considerably (from 20 to 80 km = 12 to

50 miles); so does the number of men in the gang (generally 8 to 15 men, exceptionally up to 30 men).

2. This new organisation has made it possible to reduce the number of men per kilometre. This varies considerably from railway to railway; it varies from 0.17 to 1.76 men per kilometre in the case of small gangs, and within smaller limits, from 0.10 to 0.52 in the case of the large gangs. Its average value is about 0.2 to 0.5.

3. The main factors determining the number of men are: the characteristics, and size of the installations, and the state of wear of the permanent way — the kind of services worked, the density, speed and weight per axle of the trains, the kind of formation and the climate. One Administration calculates the number of men from a formula which takes these various factors into account. In addition, the length of the section is limited by two considerations :

- the maximum number of men, who can be put under a gang foreman (i.e. 15 to 20 men; larger gangs are sometimes used, but it would seem that a gang of 10 men is the easiest for an average foreman to deal with);
- the length of the journey between headquarters and the outer limits of the section (which should not, according to some railways, exceed half an hour or thereabouts).

4. A maintenance gang generally consists of :

(Small gang) : a foreman and 2 to 5, sometimes up to 12, platelayers;

(Large gang) : a gang foreman, one or more under-foremen, and 7 to 10, sometimes up to 18 and exceptionally 25, platelayers, together with a truck driver and spare driver.

The foreman is responsible for looking after the permanent way and land in his section and organising the maintenance work in which he takes part. The number of men in the gang is sometimes reduced

to a small permanent core during the bad weather and increased by temporary labour during the most suitable working period.

b) *Housing the staff.*

5. On many railways the men are housed along their section. There is a tendency to try and group them at the headquarters of the gang, which is particularly necessary in the case of large gangs with a collective means of transport. The main obstacle to such concentration is the housing shortage in many countries.

6. The percentage of men housed in railway property varies a lot (from 6 % to 90 %). On many railways the wives of the men are employed as crossing keepers or station-masters. On nearly half the lines no men are housed in this way.

c) *Transport of the staff.*

7. The members of small gangs go from their homes to their place of work either on foot or, most often, on their own bicycles; in the latter case, although cycle tracks have been provided on a few lines, they generally have to go round by the road. Some Administrations pay bicycle allowances to men using their own bicycles, based on the mileage or number of days used. Hand operated trolleys and railcycles are also mentioned as individual methods of transport.

8. The collective means of transport used on many railways are :

- motor trolley which can haul trailers, and exceptionally hand operated trolleys;
- lorries;
- sometimes the ordinary passenger trains or buses.

The motor trolleys with which the large gangs are usually provided, have the following characteristics :

- power : 10 to 45 HP, exceptionally up to 110 HP;
- transport capacity : no. of men : 6 to

- 12 and up to 20; weight in trailer : 5 to 25 t, exceptionally 50 t;
- weight empty : 1 to 6 t, exceptionally 7.6 t;
- speed : 30 to 50 km/h. (18 to 30 miles), exceptionally 60 km/h. (37 miles).

The lorries can carry 12 to 20 men, at 40 to 70 km/h. (25 to 43 miles).

9. Trolleys make it possible to transport the men and materials to the site of work vary rapidly under good conditions, and also enable the gang foreman to note any defects in the permanent way and adjoining it; but apart from the cost and sometimes the maintenance difficulties involved, it is difficult to run them on certain lines as it is difficult to get a clear line.

The lorry costs less than the trolley and does not suffer from the same restrictions as running on the permanent way, but cannot get directly to the site of work; in addition lorry journeys are useless from the point of view of noting the condition of the lines.

10. The regulations regarding the running of trolleys are in general the same as those applying to the trains, either at a booked time shown in the service orders, or, most often, without any fixed time, a clear line being asked for by telephone. They are kept at stations adjoining the site of work, or taken off the line at the place of work, which avoids any loss of time. Communication with the stations is by means of portable telephones or telephones at fixed sites, or exceptionally by radio. Hand operated trolleys, which are generally the object of special regulations, are taken off the line on arriving at the place of work.

*d) Methods intended to encourage the staff to improve their output.*

Several Administrations (10) pay output premiums to their maintenance staff. The premiums are allocated regularly, most often not only on the amount but also on the quality of the work, taking into

account the relative values of each gang, and sometimes of each man in the gang. A few railways pay an annual premium to the gang foremen or all the men of the best gang in each region; others limit the premiums to certain operations. The amounts vary from 5 to 15 % of the men's pay. Although it is difficult to give actual figures for the improvement in output obtained thereby, it is generally admitted that premiums increase the interest of the men in their work and improve the productiveness of the maintenance work.

## **II. Modernisation of the actual maintenance methods.**

*What modern maintenance methods consist of.*

12. The old maintenance methods consisting of isolated operations carried out according to need have generally been replaced by systematic maintenance resulting in better technical results and higher output. These up to date methods can be divided into the following categories :

a) *general overhaul*, continuing over a definite mileage every year, which consists in carrying out in a given order all the operations required to remedy any defects in the sections of line in question, replacing all the materials necessary, so that the sections will remain in sufficiently good repair until the next overhaul; in addition certain defective points outside the sections are made the subject of *partial repairs*. This method, which is that most widely used, enables the different operations to be carried out thoroughly and easy supervision of the work;

b) *integral overhaul* which concerns the defective material, the level and the layout of a given part of the section every year, and *partial repairs* to certain points if necessary; this method has the advantage over the former of a more frequent correction of the level, and a more homogeneous state of maintenance of the whole section;

c) *renewal* of certain section (rails and sleepers with cleaning of the ballast), either by special gangs equipped with mechanical tools, or by hand, with methodical maintenance of the rest of the section;

d) *limited overhaul* of part of the section and partial repairs to the remainder;

e) *maintenance* according to an annual programme, based on the actual condition of the installations.

13. The cycles of general overhauls or integral overhauls vary from 1 to 6 years, exceptionally 8 years. Cycles of 4 to 6 years are the most usual. The cycles mentioned by Administrations who completely renew the material vary from 15 to 35 years.

14. In the case of a limited overhaul, the fraction of the section overhauled each year varies according to requirements: from 10 to 40 and sometimes 100 %.

15. The methods may differ on different lines of the system according to the importance of the traffic (for example, either integral overhaul or only limited overhaul), or the nature of the track (for example shovel packing on the main lines and tamping of the secondary lines in stations). Sometimes the same maintenance methods are used, but the tolerances vary, and tamping in particular is carried out with greater or lesser care.

16. The operations included in the general overhaul are the following, on many railways:

1) clearing away the ballast from the sleepers and screening it if necessary;

2) overhaul of the material and fastenings (replacing damaged rails and sleepers; overhauling the joints; checking the spacing and squareness of the sleepers; overhauling the fastenings);

3) revising the level of the layout (first lining up of the track) lifting up and rectifying the longitudinal and transversal levels;

4) re-ballasting, final lining up, squaring off the sides of the bed and formation;

5) cleaning out the ditches;

6) tightening up the coachscrews and bolts, checking deformations a few weeks later.

The order in which these various operations are carried out does not vary from railway to railway except as regards replacing damaged sleepers.

On some railways the following work is done when the renewal of rails is included in the overhaul programme:

1) cleaning of the ballast (by mechanised equipment);

2) laying the rails and fastening (by special gangs mechanically equipped);

3) lifting up the track, laying and lining up the sleepers (by special gangs tamping by means of mechanical apparatus or by hand);

4) if necessary, addition of new ballast.

17. The limited overhaul consists essentially of:

1) correcting the level, often only here and there (low joints and loose sleepers), sometimes only correcting the level transversely;

2) tightening up all the joints, and sometimes correcting the gauge.

18. The operations included in certain other methods are ennumerated below:

1) laying pre-assembled track by means of track laying cranes (renewal, not maintenance properly so-called):

— assembling complete sections of line up to 18 m long in the shops;

— loading them by crane onto special wagons;

— removing complete sections of the old track by crane;

— placing the new sections in place by means of the crane.

2) definite maintenance according to annual programmes, not following any cycles:

- maintenance of the material (especially replacement of sleepers);
- maintenance of the ballast (drainage and carrying off the water);
- tightening up the fastenings;
- correcting the level.

### **Details of the application of different maintenance methods.**

#### *A. — Maintenance of the rails and fishplates.*

19. Wear in the fishplates is generally made good by heightening them (restamping — the most usual method — building up by electric welding, cold pressing) or by the use of packings, the former method being considered the most satisfactory.

20. Welding joints, usually by the thermit process, is done by various Administrations to obtain rails 16 to 60 m (52' 6" to 196' 10 1/4") long, especially on metal bridges, in roads, and in underground sections, as well as for joining up rails of different cross-sections.

21. Building up the frogs of crossings is done by arc welding or oxyacetylene welding by various railways, but is not the general practice.

#### *B. — Maintenance of the sleepers and fastenings. Wood sleepers.*

22. Wood sleepers are most widely used. When the coachscrews or spikes cannot be tightened up properly, the old holes are used as far as possible (use of coachscrews of larger diameter, or pegging up the hole and then drilling the peg); otherwise the holes are pegged up and other holes drilled.

23. The rails rest directly on the sleepers (on the majority of railways) or on steel sole plates with double chairing surface (especially on lines with heavy traffic) or wooden or compressed cardboard plates impregnated with asphalt.

24. The ends of split sleepers are generally consolidated by steel S pieces

driven in at the ends, or by bolts. A certain number of railways bind the ends of the sleepers with flat or round steel hoops. In some cases, such measures appear of doubtful benefit.

25. To prevent gauge-widening on curves of small radius in addition to the usual method consisting of using additional coachscrews or spikes, special devices are used on certain lines or sections of line: metal tie plates, wooden wedges or steel stops coachscrewed to the sleepers on the outside of the track, cleats under the heads of the coachscrews, ties. The radius of curve after which such devices are used varies generally between 750 and 300 m on standard gauge lines and 300 to 100 m on narrow gauge lines.

#### *Metal sleepers.*

26. Very little maintenance is required with metal sleepers. Most railways build up the ends of worn sleepers. Some weld any cracks and repair worn surfaces by welding and sometimes by restamping.

#### *Concrete sleepers.*

27. Only a few railways report the use of concrete sleepers. Their maintenance is limited to replacing the sole plates and fastenings.

#### *C. — Maintenance of the level and alignment.*

28. The *level of the line* is corrected on the great majority of railways by *tamping the sleepers*, either by hand with a tamping pick, or by means of mechanical tampers which save labour and give better results.

*Measured shovel packings* is used on the lines of 9 Administrations, who consider this method has technical advantages (especially as being more accurate and more lasting), and results in economies in spite of the cost of the gravel.

29. The *alignment of curves* is generally corrected by measuring the versines by means of a line, plotting the diagrams of

the versines making it possible to calculate the exact amount of deviation to be corrected, thus avoiding proceeding by trial and error on site. Some railways prefer the direct method by the abscissae and ordinates on short curves of small radius. Permanent markers are usually set up after the rectification is completed to enable the correct curve to be maintained. Some railways make use of a calculator to determine the deviation; others use a machine which records the versines.

*D. — Maintenance of the ballast and formation.*

30. *Cleaning the ballast* is done by means of hand tools (forks and screens) on nearly all the railways. Mechanical sifters which clean both between the tracks and the spaces between the sleepers are sometimes used.

31. *Weeding the bed* is done mechanically on some lines and generally limited to the banks and ditches. The weedkiller most widely used is a solution of chlorate of soda in water, either by itself or mixed with other salts. One railway makes use of chlorate of calcium or arsenic of soda (in places where the use of this poisonous substance will not be dangerous). The concentration of the solution varies from 200 g to 10 g of salt per litre and the amount used per square metre from 0.10 to 1.5 l. The quantity of chlorate of soda spread per square metre varies according to the climate and amount of vegetation between 10 and 30 g, generally being 15 to 20 g. The weeding is done mechanically on some railways and generally limited to between the lines and the ditches. One railway reports the use of a « flame-gun » to burn the weeds; all the other railways do the weeding by hand.

*Drawing up maintenance programmes, and checking the way they are carried out.*

32. Within the limits of the annual budget the railways prepare a maintenance programme, after the matter has been considered by various officials, which generally

takes the form of a monthly programme of work, completed by a table giving the estimated number of man-days and quantities of material required.

The work carried out each month is checked by means of graphs and tables showing in particular: the overhaul work done, the number of days spent on the different operations and the amounts of materials supplied. The results obtained are checked by visits of inspection during which measurements are made of the track, either directly or recorded by machines run over them periodically, the results of which tests are sent to the supervisory staff in order that any defects discovered may be corrected.

*Tolerances allowed on the basic figures for the permanent way and its equipment.*

33. *Wear of rails.* — On some railways the wear allowed is expressed in weights (8 to 22 %). Generally the tolerance for vertical wear varies from a minimum of 5 mm (13/64") for 20 kg/m rails to 20 mm (25/32") maximum for 50 kg/m rails. The lateral wear allowed varies from 3 to 19 mm (1/8" to 3/4"). On some railways, the limits allowed in the case of vertical wear are reduced to one half of the lateral wear.

*Sleeper thickness before replacement.* — The railways who have adopted standard specifications allow a minimum thickness of the sleepers after recutting of 7, 8 or 9 cm and exceptionally 10 or 11 cm. Some railways stipulate that they shall be re-used on sidings as soon as the rail cuts in to a depth of 2.5 cm.

*Gauge of the track.* — The tolerances allowed vary considerably within the outer limits fixed for the gauge of the track: from 12 to 2 mm under to 5 to 12 mm and exceptionally up to 25 mm over.

*Variations in the level.* — Many railways do not specify any tolerances in this case. The buckling of the track allowed is generally 1 to 3 mm per metre; it may sometimes be 6 mm per metre between two points at least 3 m apart. The incor-

rect superelevations allowed lie between 10 mm under and 10 mm above the fixed readings.

### III. Modernisation of the equipment.

#### A. — Tools and machine tools used for the maintenance of the rails and joints.

34. *Drilling the rails* is generally done by hand tools (ratchet or mechanical drills worked by a cranked handle). In addition some railways use power driven drills, either electric (using a mobile generating set), or pneumatic, or petrol-engine driven. Hand operated drills take 2 to 5 times the time required by power driven drills.

35. *Cutting rails*. — This is generally done by hand saw. Some railways use hand operated sawing machines and others motor driven equipment. The advantage of the latter is the greater regularity of cut obtained rather than the saving in labour (time to make a cut reduced from 20 to 10 minutes).

36. To regulate joints that have got out of place owing to creep, hand operated « joint-pulling » machines are frequently used; they save 50 % of the time normally taken to do this work.

37. *Tightening up the fishplate bolts* is generally done by ordinary spanners, or ratchet spanners, and sometimes by two different sizes of spanner (a long one to loosen the nut, and a short one to turn it rapidly). Some railways use petrol driven apparatus (requiring 3 men to operate it, but the output per man is increased by 500 %), or pneumatic equipment.

38. The *welding of joints* is done either by the classic aluminothermic equipment, or by electric welding equipment with petrol or Diesel engines. The building up of the frogs of crossings is sometimes also done by oxyacetylene welding with drilling and grinding (taking about 6 hours) with an electric motor. Building up the ends of rails is done on a reduced scale.

#### B. — Tools and mechanical plant used for the maintenance of the sleepers and their fastenings.

39. Drilling the holes in wood sleepers for the coachscrews and spikes is generally done by means of augers, or drills (the output of which is double that of augers), sometimes completed by reamers in the shape of a truncated cone. The mechanical plant used on several railways is driven either by electric motor, or more frequently by petrol motor (output 300 to 400 holes per hour, i.e. about 10 times that of hand operation).

40. *Driving and removing the coachscrews* is generally done by hand by means of an ordinary spanner, or sometimes by a mechanical coachscrew driver which requires less muscular effort. Motor driven tools are also in service on several railways: electric coachscrew drivers (output 6 to 8 times greater than by hand), pneumatic coachscrew driver, and petrol engine driven coachscrew drivers (number of coachscrews driven or removed per hour: 200 to 500, compared with 50 to 60 using a spanner).

41. *Truing up the rail seats of the sleepers and recutting the shoulders* is done by hand using adzes, saws and wood chisels on the greater number of railways. Mobile engine driven planers the use of which necessitates the removal of the rails and sole plates, are used on some railways. Mechanical shapers enabling the shoulders to be re-cut very quickly and accurately are used by several railways.

42. The *consolidation of split sleepers* is done on several railways by fitting hoops by hand.

#### C. — Tools and plant used to rectify the level and alignment.

43. The track is generally *lifted* by rack and pinion jacks. Instead of these ratchet jacks are sometimes used, which are lighter, can be removed from the line when trains

are passing, and make it possible to let the raised up track fall abruptly. One Administration reports the use of a petrol driven jack worked in conjunction with a mechanical tamper and requiring 3 men.

44. *Tamping* is usually done by hand by means of tamping-picks, rammers, shovels or forks according to the kind of ballast used. Some railways use power driven plant, the tampers of which are operated either pneumatically or electrically and act by percussion, or tampers driven by Diesel engines whose tampers have a vibratory and traversing movement and compress the ballast under the sleepers.

45. The equipment used for *measured shovel packing* consists essentially, in addition to the equipment for measuring the levels, hand operated shovels. One Administration reports the use of mechanical plant which vibrates the ballast, used when the latter consists of gravel or cinders.

46. Recording the versines of curves, in order to *correct* any errors, is done graphically on some railways by means of equipment fitted on a articulated frame.

**D. — Tools and plant used for the maintenance of the ballast and formation.**

47. Chemical *weed-killing* is done either by weedkilling trains (consisting of tank wagons or tenders with spraying equipment), or by tanks mounted on trucks with a pump operated by one of the axles and hauled by a truck), or by two wheeled atomisers consisting of a tank and a pump operated by a petrol engine, or by hand atomisers, the tank being carried on the operator's back.

48. Mechanical *weeding* is done by rotary picks, motor cultivators, extirpators and screens, or ploughs to make fire-guard belts or to keep the banks tidy. One railway uses a 5 burner flame gun to burn off the weeds on the track.

49. The ballast is *cleaned* by means of picks and screens. Two Administrations use respectively a small vibrating shifter

worked by a petrol engine and a larger apparatus which collects the ballast, shakes it, throws out the rubbish and puts the cleaned ballast back.

50. Amongst the other equipment used mention may be made of :

- hand operated rake-plough to clean and respread the ballast;
- plant mounted on a truck consisting of 2 shares for cleaning the ballast near the ends of the sleepers and in between the rails;
- plant for mechanical track renewal;
- clearing and shifting plant for cleaning the ballast;
- steam or motor driven shovels with self-tipping wagon;
- grinders on slides to correct corrugations on the rails;
- lime spreading trucks to disinfect and purify the underground lines of metropolitan railways.

51. A few examples were given of the details of organisation when mechanical plant is used :

- general overhaul of the fastenings and joints using a motor-driven coach-screw driver, mechanical shaper, and motor drill, with a gang of 10 to 14 men;
- replacing sleepers by « gravillonage » using 2 mechanical coach-screw drivers (length of section 600 to 800 m; output : 15 sleepers per man per day);
- laying rails by means of mechanical plant to the greatest possible extent (using 94 men equipped with 23 machines, whereas 198 men would be required if all the operations were done by hand, so that mechanisation results in a saving in labour of 104 mm, i.e. 52 %).

**IV. Results obtained.**

52. From the technical point of view, as far as the quality of work is concerned :

a) owing to the organisation into larger gangs responsible for longer sections, supplied with transport, it is generally agreed that the application of the overhaul methods and the supervision of the work are better assured, such an organisation being necessary for the working of mechanised gangs, and making it possible to provide the desired labour at any point very quickly. However opinions are divided concerning the improvement in the average condition of the permanent way due to grouping the staff in this way;

b) on the other hand, the efficacy of the new methods is more or less unanimously agreed: the more systematic the organisation, the better the state of the track, the maintenance work being carried out with greater precision, and thus being of more lasting value;

c) the use of mechanical equipment results in a better quality of work than that obtained by hand operation (for example, the slope of the coachscrew holes is more accurate, the re-cutting of the shoulders of the sleepers done more regularly, etc.).

53. From the economic point of view, as regards output:

a) the grouping of the staff into large gangs generally saves labour (estimated at 5 to 15 %). Certain Administrations consider such grouping is necessary to obtain rational organisation of the work. Others consider that it does not as a rule result in increased output per man, although it does make it possible to keep the track in a suitable state of repair on lines with little traffic with the smallest possible amount of labour. Finally, the results are only satisfactory when various factors are fulfilled: efficient foreman, grouping of the staff at headquarters or nearby, rapid transport available, normal state of repair of the track without too large a number of special points.

If these conditions cannot be fulfilled, it would seem better to retain the small gangs, whose members often have a greater

feeling of solidarity. For this reason certain Administrations remain faithful to the traditional organisation;

b) the effect upon the output of the new methods is often difficult to estimate, when they are introduced at the same time as the provision of mechanical equipment or the grouping of the staff into large gangs. However the Administrations, who have applied these methods for a certain number of years have supplied information showing that they have appreciably increased the output and made possible a saving in labour of sometimes as much as 20 to 25 %;

c) the use of mechanical plant has again increased the output, as several examples show:

- track laying with the most complete mechanical equipment available saves more than 50 % of the labour (see above under 51);
- the use of mechanical spanners makes it possible to double or treble the output (3 men can tighten up the coachscrews on 1 500 to 2 400 m of track instead of only 800 m by hand);
- the use of power driven coachscrew spanners and drills enabled the following saving in labour to be made: 750 % to 2 000 % on the time required for the separate operations;
- 40 % of the hours required for overhauling the fastenings, when mechanical coachscrew drivers are used;
- 17 % of the men required for general overhauls when such tools are used;
- by the use of a small tamper, a gang can double its output.

But, it is necessary to study very carefully the organisation of the work, in order to obtain the maximum output from the equipment, and to have skilled operators and a suitable centre for maintaining the equipment.

## 54. From the social point of view :

a) the use of collective transport makes it possible to decrease the fatigue of the men and reduce the amount of handling, provides shelter from bad weather during travel to work (in addition the gang can use it as a shelter near the place of work). The grouping of the staff often improves the social conditions under which the men and their families live, especially when the line runs through sparsely inhabited country (shopping and travelling facilities, schools for the children, medical facilities). On the other hand, on certain railways, such grouping has the drawback of decreasing the number of men whose wives can be employed as station masters or crossing keepers, living in railway owned property;

b) owing to the application of the new methods, it appears that working conditions are improved on the whole, and the increased output is obtained not at the expense of greater fatigue on the part of the men, but from the reduction in time wasted, and unfruitful operations, and by the use of more suitable equipment. In addition the work is more interesting and attractive; the men have to have greater technical skill, and are no longer mere labourers;

c) owing to the mechanisation of the work the fatigue of the worker is diminished. Although the introduction of mechanical plant is not always popular, in the end it is appreciated by the men and their supervisors. Some Administrations are of the opinion that the interest of the men in their work is increased and the work advances at a greater pace; however this is an unconfirmed opinion. In addition, the use of mechanical plant increases the number of specially qualified men who can expect to receive higher wages. On the other hand the main drawback found on railways where mechanisation is carried to a high pitch is that the staff, accustomed to using mechanical plant, do not like to do the work by hand when no machines are available.

*Arrangements under consideration to make further improvements in modern maintenance methods.*

55. The present tendency on railways, who have applied these various measures, is to follow them up by investigating further possibilities. Others are considering equipping themselves with the plant they consider most suitable for their special conditions. But for several of them, the capital required to acquire mechanical equipment makes such modernisation impossible; for others, the need to employ sufficient men to carry out much other work, apart from the maintenance of the track properly speaking, reduces the economic interest of mechanisation. Amongst the steps proposed by one railway, mention may be made of the creation of large gangs of a total of 37 men, equipped with an 80 HP truck, which is able to haul 50 t, and with mechanical plant including two coach-screw drivers and two drills. The total output of such a gang should make it possible to add a further 10 % to the previous saving of 20 % in labour.

### Summaries.

1. The question of the modernisation of permanent way maintenance methods can be divided into 3 parts :

a) modernisation of the maintenance properly so-called (very generally applied);

b) modernisation of the organisation of the staff (applied on many railways);

c) modernisation of the equipment (only applied on some railways).

2. *Maintenance methods.* — Most of the railways have replaced haphazard maintenance as required by various periodic overhauls, taking place every year on some section of the line. The methods most widely used are the following :

— *general overhaul* of a section according to a programme including the carrying out of all operations required to correct any defects (maintenance of

- the material and fastenings, the level and alignment, the formation), with *partial repairs* according to need at certain points outside these sections;
- *integral overhaul* of a part of the line, affecting the material, the level and the alignment, with *reduced overhaul* of the level and tightening up the fastenings of another part, and for the rest of the lines, partial repairs as required as above.

The length of the overhaul cycles is generally 4 to 6 years.

Some railways renew the rails and sleepers on certain sections of the system every year.

Opinions are more or less unanimous on the efficacy of such systematic maintenance; the work is carried out with greater precision, lasts longer, and supervision is easier; the increase in the output obtained generally makes it possible to make economies in labour.

3. Various satisfactory methods are used for the conservation and consolidation of the material, in particular :

- restamping the fishplates or inserting packings;
- welding rail joints and building up the frogs of crossings;
- re-using damaged holes in the sleepers by using wooden pegs and drilling the pegs, or by using packings or wedges;
- conserving the bearing surfaces by the use of sole plates or wooden bearing plates;
- binding split sleepers;
- maintaining the gauge on curves of small radius by the use of wedges, stops, plates, cleats or ties.

4. The railways using measured shovel packing get greater precision and a better output than from tamping.

5. The correction of the alignment by the versine method with a calculation of the errors and marking the correct position, used by many railways (sometimes with

the assistance of a calculating machine) makes it possible to get regular curves without proceeding by trial and error on the site.

6. Chemical weed-killing is replacing hand weeding on most railways; the most usual weedkiller is chlorate of soda in solution in water, or pure, or mixed with other salts.

7. All the railways prepare maintenance programmes and check the way these are carried out by preparing graphs or tables and by other measurements made directly or recorded by equipment run over the line.

8. *Organisation of the staff.* — On a large number of railways, the practice of dividing the staff up into small gangs has been given up in favour of large gangs maintaining longer sections. The size of the sections and optimum number of men differ appreciably from railway to railway. This organisation makes it possible to reduce the labour required, and facilitates the application of overhaul methods and the supervision of the work, so long as certain conditions are fulfilled.

9. The homes of the men are generally sited alongside their sections, sometimes in the railway buildings. In the case of large gangs it becomes necessary to group them at headquarters; difficulties may be encountered due to the shortage of houses, but there may also social advantages, especially in certain very sparsely populated districts.

10. The transport of the staff to the place of work is either by individual means (most often bicycle) or collective (trucks, lorries, passenger train or bus). The large gangs usually are provided with motor trucks hauling trolleys.

11. In order to stimulate the output of the gangs, several Administrations grant output premiums. It is generally considered that such premiums give good results.

12. *Mechanisation of the equipment.* —

Some railways make use of mechanical tools and plant worked by hand or engine driven (drills and saws for rails, jointing pulling apparatus, coachscrew spanners, drills for sleepers, coachscrew drivers, cutters and shapers, sleeper hooping machines, mechanical tampers, etc.). The most widely used mechanical equipment are coachscrew drivers and sleeper drills. These machines save labour, whilst doing the work more accurately and less tiringly. But it is necessary to have skilled men to drive and work them. In addition their methodical use, generally as laid down in the track overhaul programme, must be on a large enough scale to make good their cost.

13. The results obtained by the application of the overhaul methods, the grouping of the staff into large gangs, and the mechanisation of the equipment, are generally considered satisfactory from the three points of view of technical efficiency, economic results, and social results, although it is often difficult to show the results attributable to each of them in the balance sheets.

The railways using such methods tend to extend them. Other railways are considering their adoption to some extent. In particular, the use of motor-driven tools, which is still very limited, might with advantage be developed.

#### QUESTION XIV.

## Change-over from steam-locomotive traction to Diesel traction,

by U. CANTUTTI, Engineer,

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Special Reporter.

### FOREWORD.

For some dozen years steam traction has found itself in competition with more recent types of traction, i.e. electric traction and that using the Diesel engine.

Diesel traction, which developed so rapidly in North America, has also been the subject of lively attention in Europe during the last twenty years, especially as regards light units, and more recently in the Colonies also, where it has found a wide field of use.

The question forming the subject of the present special report was intended to throw light, by means of an extensive research over a very large number of railways, upon the reasons why many Administrations have decided to go in for Diesel traction or consider its use, and the results and conclusions at which they have arrived.

The questionnaire sent in August 1949 to 81 Administrations, members of the Congress, was drawn up in this spirit. Of them, 52 replied, but only 23 supplied information of value.

The question was the subject of the two following reports :

Report (America (North and South), Burma, China, Egypt, Great Britain and Northern Ireland, Dominions, Protectorates and Colonies, India, Iran, Iraq, Malay States and Pakistan), by A. W. OLIVIER. (See *Bulletin* for June 1950, p. 1419.)

Report (Austria, Belgium and Colony, Bulgaria, Denmark, Spain, Finland, France

and Colonies, Greece, Hungary, Italy, Luxembourg, Norway, Holland and Colonies, Poland, Portugal and Colonies, Rumania, Sweden, Switzerland, Czechoslovakia, and Turkey, by M. DIEGOLI. (See *Bulletin* for September 1950, p. 1927.)

The object of this special report is to sum up the above two reports and give the summaries resulting from the enquiries carried out by the Reporters in the different countries consulted.

Owing to the extent of the subject, it is convenient to divide it into three chapters :

- A) Train locomotives;
- B) Shunting locomotives;
- C) Railcars.

### A. Train locomotives.

Mr. DIEGOLI's Report shows that 160 locomotives are in service at the present time and many others under construction on a total of 14 railways in Europe and Africa. These locomotives were put into service between 1927 and 1950; the powers generally do not exceed 1 500 HP with the exception of two trial locomotives on the S. N. C. F. (4 000 HP).

The Danish State Railways and above all the Algerian Railways, who have had Diesel train locomotives in normal working for many years, have very considerable experience of the subject, which makes the favourable results reported by them of particular importance.

In the case of the African Railways, although the length of the systems and above all the stock of locomotives are much lower than those of the European Railways, the number of Diesel locomotives in service or under construction is proportionately much higher.

Amongst the European Administrations, the Portuguese Railways and Austrian Federal Railways also have in service or on order a relatively large number of Diesel train locomotives, but any information regarding the operating characteristics and constructional details is lacking; it can be assumed however that these engines are intended for services on other than the main lines.

To conclude, in the European countries, Diesel traction, the development of which is founded upon reasons of an economic nature, though the possibility of making the services faster and more flexible is not being overlooked, is still at the stage of trial and observation; probably the railways now set on electric traction look upon Diesel traction as a means of solving particular economic conditions on lines with little traffic, whilst, in order to meet the requirements of speed on important lines in the case of fast long distance trains, until electrification is possible, they can find a useful solution in railcars, which will be dealt with later.

It should also be stressed that the cost of fuel on most European Railways (liquid fuels are imported) has a great effect upon the general operating economy and the ratio of the outputs of the two types of engines (Diesel and steam) will be changed to a certain extent by the ratio of the unit cost per calorie for the two types of fuel.

Conditions are very different in the case of the North American Railways where Diesel-electric traction has already achieved a particularly rapid rhythm of development.

About 2 000 Diesel-electric train locomotives are in service in the United States, varying from 1 500 to 6 000 HP.

Standardisation of the prototypes is already far advanced.

The standard units are 1 500 and 2 000 HP and 3 000 to 6 000 HP can be obtained by coupling two, three or four units together.

The steam locomotive is on the decline; practically no important orders for steam locomotives have been received by the U. S. A. locomotive builders from the main line railways since the war.

In the United States, the Diesel-electric locomotive is in the lead, both in the case of passenger and of goods trains, and also for shunting.

The economic advantages have been proved by the years of wide scale operation.

The only competitor in the future for the Diesel-electric locomotive might be the turbo-electric locomotive with internal combustion turbine.

Many African and Colonial Railways, where steam traction is handicapped by difficulties in the water supply, both as regards quality and quantity, by the high cost of coal delivered at the place where used, by the small average speeds possible, by the unduly low average utilisation of the locomotives, and by the other well known disadvantages connected therewith, find it essential to have a more powerful and more independent method of traction, better adapted for long runs, since it is self-contained and capable of giving an elastic and sufficiently fast service, even on lines of light construction with frequent small radius curves. Since electrification is generally impracticable or unsuitable, owing to the traffic, Diesel traction is in a particularly favourable position. A clear tendency in this direction is already perceptible, and it seems likely that in such countries Diesel traction will end by replacing entirely steam traction within a fairly short time.

As it is not possible to make a direct comparison of the operating figures given in the two cases for the different countries (excluding the United States) since the information supplied in general lacks uniformity. For example :

1) the monthly mileages, included between 28 000 and 5 000 km, are sometimes plainly superior to the mileages of steam locomotives, sometimes inferior; and the average mileages in normal service, without change of locomotives are between 65 and 255 km;

2) the average power user coefficients are included between 50-80 and nearly 100 %;

3) the purchase and operation costs are affected by the purchase period, the currency value; the cost of fuel and salaries;

4) the mileages between two general repairs are between 120 000 and 300 000 km.

However, it will be noted that as regards availability and utilisation coefficients, the average data supplied by the Algerian Railways are not far from those obtained in America. It can be concluded that a rational use of the Diesel makes it possible to obtain without difficulty availabilities exceeding 70 and 75 %, and utilisation reaching 55 and 60 %.

The monthly mileage in the case of the North American Administrations exceeds 25 000 km in the case of passenger locomotives, but much higher figures (40 000 km) have been obtained in continuous passenger train services over long distances.

The continuous mileages away from the shed are truly remarkable in the United States (up to 3 500 km without change of locomotive) before it is necessary to refuel.

Nothing on the European Railways approaches this.

As for the data concerning operating costs, only the Danish Railways, amongst the European systems, gave comparative figures for Diesel and steam traction.

These revealed a total saving of 50 % for 500 HP units and 42 % for 900 HP units, with a saving of 75 % and 68 % respectively if fuel costs only are considered.

It would seem that from the general point of view these results should be considered rather optimistic and the result

of special conditions; the Netherlands Railways, for example, during 1949 found there was a saving of 54 % on fuel alone in favour of Diesel traction.

The most common technical solutions in the construction of Diesel train locomotives are as follows :

*Diesel engine.* — There is a tendency to concentrate the power in a single 4 stroke engine (in Europe), sometimes 2 stroke engine. Between 1 000 and 2 000 HP may be taken as standard for main line services.

Supercharging is general with turbo-blowers, sometimes using part of the thermal energy of the exhaust gases. Number of cylinders : minimum 6; maximum 16. Water cooling, the water being circulated by a separate electric pump.

Lubrication with closed circuit with cooling and filtering of the oil.

The main generator is always multipolar with 6 to 12 poles directly coupled to the engine. The exciter can be driven by the main engine or form part of the auxiliary group.

The generator is cooled by natural ventilation.

The traction motors are of the series or compound type; the electric coupling is either single combination or double combination. The engines are nose or totally suspended, with quill drive.

Cooling by forced ventilation by means of separate motor fans.

Regulation of the power by notches, assured by excitation linked up with the regulation of the speed of the Diesel.

To complete the equipment, in addition to the different auxiliaries (motor fans, motor compressors, lighting, etc.) there is a large capacity accumulator of the light weight type, which supplies the control circuit and starts up the Diesel.

The battery is charged by the exciter. The percentage distribution of the weight of the different parts of the equipment of the Diesel locomotive is on the average :

Mechanical part . . .	40 % of total weight
Diesel engine . . .	20 % of total weight
Electrical part:	
Generator . . .	9 %
Tract. engines. .	15 %
Equipment and auxiliaries . .	3 %
Accumulator . .	3 %
Fuel, water, lubricants, etc. . . . .	30 % of total weight
	10 % of total weight
	100 %

On the European Railways, there is no report of any installations specially designed for Diesel traction (factories, shops, refuelling depots, etc.); there are no sheds for the exclusive use of Diesel train locomotives (there are some sheds exclusively for railcars).

On the contrary in the United States, the development of Diesel-electric traction for the train services has led to a complete special organisation for the fixed services from the building of refuelling platforms (inspection and supply) to train shops (maintenance) and main repair shops.

Each of these buildings has special characteristics differing from those found in the usual buildings for steam traction.

### B. Shunting locomotives.

Nearly all the European Railways, even those which have no Diesel train locomotives, have adopted a certain number of small Diesel locomotives or locotracitors for their shunting services (<sup>1</sup>). The small Diesel locomotives are naturally used for the heaviest services.

The number of such small locomotives is very remarkable compared with the number of Diesel train locomotives. The most striking facts are the following:

11 Administrations own or have on order

(<sup>1</sup>) The term locotractor is reserved for engines, generally 4 wheeled, of not more than 200 HP.

254 shunting locomotives and 520 locotracitors; other Administrations expect to put the locomotives and locotracitors they have on order into service very shortly. All these engines are run on gas oil; only Norway makes use of petrol engined tractors.

The highest figures were supplied by the S. N. C. F., Italian State Railways and Netherlands Railways, who have respectively 106, 49 and 73 Diesel shunting engines and 257, 186 and 200 locotracitors.

The types of locomotives and locotracitors about which details were supplied were very numerous; but certain types are characterised by a development which appears to be of a final character.

As regards shunting engines, the following data were received which throw light upon the tendencies on the Administrations the best equipped with such engines:

*S. N. C. F.* — Will complete the series of three classes of locomotives characterised as follows:

1st class. — Weight 51-54 t; 360-380 HP; hydro-mechanical drive. Two prototypes have just been put into service.

2nd class. — Weight 51-54 t; 500 HP electric drive. 48 units under construction. These locomotives can be coupled up in pairs or worked in conjunction with a 6 wheeled truck-tractor, carrying spare tanks, whose electric engines are branched off the generator of the locomotive being used together with its own engines, which makes it possible to shunt 1 800 t/trains.

3rd class. — Designation A—I—A+A—I—A; weight 109 t (adhesive weight 72 t); 750 HP at 625 r.p.m.; maximum speed 96 km/h. (59.65 miles); tractive effort at the tread lying between 13 500 and 1 100 kg. The type of drive is to be fixed according to the results obtained with the prototypes of the 1st class.

*Italian State Railways.* — The 49 locomotives comprising the stock of the F. S. are characterised as follows:

Designation Bo+Bo; weight 59 t; 325 HP

at 1 200 r.p.m.; maximum speed 74 km/h. (46 miles); electric drive.

*Netherlands Railways.* — The shunting engines can be divided into 3 classes :

1st class. — Designation Bo; weight 37 t; 250 HP; electric drive.

2nd class. — Designation C; weight 52 t; 355 HP at 680 r.p.m.; electric drive.

3rd class. — Similar to the F. S. locomotives in every way. A total of 73 units.

*Locotractors.* — These engines can be considered as simplified Diesel locomotives.

The S. N. C. F. is going to complete the series of 3 classes of locotractors whose weight lies between 8 and 32 t; 25 to 135 HP; maximum speed between 30 and 60 km/h. (18 and 37 miles). In the future, this Administration proposes to use mechanical drive in all 3 classes.

The Italian F. S. have two classes of locotractors, whose weights lie between 6.5 and 12 t; 65 to 105 HP; maximum speeds between 25 and 41.5 km/h. (15.53 and 26 miles). The drive is mechanical and the engines are fitted with a device making it possible to increase the adhesive weight by taking part of the weight of the next wagon on the tractor.

Trials are to be carried out concerning the use of 105-200 HP locotractors to haul light goods trains, on secondary lines.

The Netherlands Railways have about 200, 21 t; 72 HP locotractors, with electric drive.

The information summed up above enables us to make the following observations.

Shunting falls into different categories according to the operations to be carried out, viz. :

- moving vehicles and engines in the shed, shops and small stations;
- shunting in yards of some size;
- heavy shunting services and use in large marshalling yards.

In order to have as high as possible a

coefficient of utilisation of the tractive effort, in the different cases, it has been recognised that it is necessary to have three classes of engines.

The first class (locotractors) of low weight (about 20 t) nearly always has mechanical drive.

The second class consists of engines, whose weight lies between 20 and 50 t, up to 400 HP. These are small locomotives with one or two high speed 4 stroke engines, with main generator and 1 series-motor per axle; the electric power is regulated in some cases automatically, and in others by electro-mechanical means.

The third class consists of units whose weight and power are higher than those of the 2nd class (up to 750 HP and 72 t adhesive weight in Europe, and 1 000 HP in the U. S. A.).

It should be pointed out that many of the class 2 and 3 locomotives came from the American army and certain Administrations are considering the possibility of adopting hydro-mechanical drive even for the locomotives of these last two classes.

In all cases only one man is needed to drive the shunting locotractors, which is also the case with the Diesel locomotives except in a few countries, for non-technical reasons. The « dead man's handle » is only used on some Administrations.

The replies given to the question regarding operating figures for the shunting engines give rise to the following considerations :

a) the coefficients of availability and of utilisation reported by the various Administrations concerned are generally high. The Italian State Railways give the percentage of availability and utilisation of the locotractors as 97 %.

The corresponding number of vehicles shunted per day is 14 to 15. It must therefore be concluded that the coefficients mentioned are theoretical and do not correspond to the real utilisation of the locotractors. The same applies to the figures given by the French S. N. C. F.;

b) the average number of vehicles shunted per day by a locotractor does not exceed 15 to 20; this figure is obviously not an indication of the capacity of the locotractor, but rather of the nature of the work (intermittent shunting in small stations) for which this type of Diesel locomotive is used.

Insufficient data are available to decide whether the average number of vehicles shunted per day by the Diesel locomotives in the important yards exceeds the number for steam locomotives, and by how much;

c) as regards the average coefficient of utilisation of the tractive effort in working Diesel shunting locomotives, the small amount of figures available give no useful indication;

d) no Administration has reported any serious drawbacks;

e) nearly all the Administrations agree more or less regarding the amount of the fixed annual charges (amortisation and other costs), which oscillate between 7 and 10 %.

Only the Danish Railways report a higher rate (about 33 %);

f) as regards the cost per hour shunting (or per kilometre), the information supplied enables fairly definite conclusions to be drawn.

The ratio (for the same powers) between the cost of shunting by Diesel or steam locomotive is approximately :

— Danish Railways . . . . .	0.9
— Italian State Railways . . . . .	0.7
— Belgian National Railways . . . .	0.6
— Algerian Railways . . . . .	0.53
— Great Britain (Eastern Region) . .	0.50
— Great Britain (Western Region) . .	0.41
— United States (Pennsylvania) . .	0.40

As regards the cost of repairs per unit of fuel used, the figures supplied agree fairly well.

The average is 15 to 20 fr. per litre of fuel.

### C. Railcars.

The use of railcars for passenger traffic greatly increased in Europe after the last war, as a result of the shortage of ordinary coaches and locomotives, but the technical success achieved both as regards the engines and in the construction in general justify the view that certain types of railcars will continue to be used on the main lines, and for long distance services.

The non-European Administrations, such as those of the United States of America or Australia, have a very limited number of railcars compared with the size of their systems, and their use is limited to secondary lines.

Mr. DIEGOLI's Report gave some very important figures: 10 main line railways own a total of 2 169 railcars whose average age is 10 to 12 years, and on certain railways the percentage of the train/kilometres worked by railcars is below 20 % and sometimes reaches a much higher percentage in the case of railways with little passenger traffic.

These railcars are used :

a) for passenger train services (stopping and through services) on secondary lines, with little traffic, for short or average journeys;

b) for express and ultra-rapid passenger services on the main lines for long distance services.

The use of railcars for other than passenger services is limited to a very few exceptional cases.

The characteristics of the railcars differ very considerably from one railway to another, but they have a certain similarity of construction on each railway; the differences are due to the requirements of the different kinds of service for which they are used.

In all the types of railcars, the characteristics of light construction can be seen, together with the fullest possible use of the available space, and the tendency to increase the nominal horse power.

Electric drive, which is expensive and heavy, has been replaced in most cases by hydraulic or mechanical drives, even for high power railcars (500 HP on the Austrian Federal Railways).

There are one or two engines; their number does not depend upon the power of each unit but rather on the type of construction and service for which the vehicle is to be used. The engines are sited on the chassis or on the bogies, or below the body; this latter arrangement makes it possible to increase the number of seats available.

There are very few 4 wheeled railcars.

The maximum speeds on the level differ considerably according to the type of service for which the railcar is used; in general they lie between 60 and 130 km/h. (37 and 81 miles), and may be as much as 140 to 150 km/h. (87 to 93 miles) in the case of the R type of the French National Railways.

The VT/45 and VT/145 types of the Austrian Federal Railways should be noted, in which the passenger compartments have been arranged in two decks, thus giving a total capacity of 113 seats in a vehicle 27 m long.

The weight empty naturally varies widely compared with the number of seats, the power of the engines and the type of drive.

Nearly all the railcars can haul a trailer; sometimes they are of the articulated rake type, of from 2 up to 5 units; in some cases (for example the Netherlands Railways), two rakes can be run as a twin unit with single control; this system has not been extended to any degree, as combinations of railcars and trailers are preferred to the articulated rakes.

The specific powers per ton of full load are very variable; they are not generally lower than 5 HP, but are frequently 10 and even 13 HP (S. N. C. F.).

In view of the fact that mechanical or hydraulic drive generally only works on one of the two axles of a bogie or on the

two axles of one bogie, it follows that the adhesive weight of a railcar is normally 50 %.

When it is considered that the weight of a trailer with the same constructional characteristics as the motor unit may be taken to be 0.70 of the weight of the latter, it will be seen that the ratio:

Adhesive weight  
Total weight may reach values of:

with a single trailer: approx. 0.3;  
with two trailers: approx. 0.2.

Consequently, the maximum accelerations obtainable on the level (supposing a specific power of 10 HP per ton for the railcar) are:

- with 1 trailer: approx. 0.49 m/S<sup>2</sup> (up to a speed of 30 km/h. [18.6 miles]);
- with 2 trailers: approx. 0.31 m/S<sup>2</sup> (up to a speed of 35 km/h. [21.7 miles]).

It will be seen that operating with two trailers can come close to the limits for railcar traction, beyond which it is better from every point of view to use a Diesel locomotive.

Naturally in the case of stopping services with frequent stops, operating with two trailers does not seem of much value from the point of view of the time saved over operating with a locomotive. In this connection, the Belgian National Light Railways do not intend to adopt trailers for their railcar services.

In addition, should it indeed be concluded that the American have not gone in for railcar services with high powered railcars on their lines with heavy and medium traffic because of the above mentioned considerations?

Railcars owe a great part of their success to the very high maximum and average speeds, which they make possible. Even the daily mileage reaches a considerable figure; in effect the average daily mileage varies between 200 and 250 km (124 and 155 miles) for the low and medium powered types up to 400 km (248 miles)

for the powerful units (above 400 HP) used for the fast services.

The maximum daily mileage is as much as 700 km (434 miles).

Services are often worked over gradients of 25 ‰, but also on lines with gradients of 30 ‰ and exceptionally 40 ‰.

The adhesion railcars on the Paola-Cosenza line of the Italian State Railways work on a line where there are many gradients of 75 ‰.

The rack brakes have been found unnecessary, and on the new railcars for the narrow gauge lines in Sicily the rack brake has been suppressed and replaced by a Westinghouse « motor brake » type.

The data concerning performances on gradients were too incomplete to enable us to establish the degree of flexibility obtainable with the different types of drive.

However, it appears that the best performance from the point of view of flexibility is given by the electric drive; especially if the regulation of the Diesel dynamo makes it possible to use the power of the engine according to the formula  $EI = \text{constant}$ , independently of the speed.

As regards the coefficients of availability and utilisation, and the monthly mileage, breakdowns in service, purchase price, the fixed annual charges, and the operating costs, the details supplied by the different Administrations are not at all homogeneous, perhaps on account of the great differences in the types of railcars used and in the kind of services for which they are used.

The monthly mileage varies between 5 000 up to 10 or 12 000 km (3 100 to 6 200 and 7 460 miles).

The coefficient of availability lies between 50 % and 85 % (average 75 %), and the coefficient of utilisation between 40 % and 80 % (average 70 %).

The purchase prices in absolute value of each unit cannot be compared with each other; however the following figures can

be given: (very approximative and relating to recent railcars for speeds of more than 100 km/h. [62 miles]):

Average cost/HP . . . 60 to 100 000 fr. a)

Average cost per seat 200 to 450 000 fr. b)

Even the operating costs vary within wide limits from country to country, namely:

	from :	to :
Fuel . . . . .	8 %	47 %
Lubricants . . . . .	0.8 %	14.5 %
Driving . . . . .	14.5 %	42.3 %
Maintenance . . . . .	21.8 %	60 %

Obviously, it is impossible to draw any general conclusions from these data.

It should be noted that whenever railcars have been adopted, the average speed increased by at least 15 to 20 % (for fast services on important lines), 25 to 35 % (for stopping trains according to the gradients), and up to 50 and 60 % for services on colonial or secondary lines.

The increase in the average and maximum speeds in the case of the passenger services should be considered as one of the reasons for the success of railcars, especially when it is remembered that there is little reduction in the average speed if trailers are used on trains with infrequent stops.

Consequently, all recent designs of railcars are intended to haul trailers. When multiple units are used the control of the engines and signalling and safety devices are often coupled up together; it is often possible to get from one unit to another in the case of multiple units, or between the motor unit and trailer.

The coupling up of several railcars together or with trailers does not of itself lead to any restrictions on the speed.

a) The lowest figures relate to railcars with sufficient power so that they can haul trailers;

b) the highest figures relate to railcars intended to haul trailers and run at high speeds.

Generally two men are employed to drive railcars, but this is not for strictly technical reasons. The « dead man's handle » is only used in Austria and to some extent in France, Czechoslovakia, Norway and Holland.

As regards driving the unit when several railcars are coupled together, the following two tendencies are to be noted :

*a) single control and repetition of the*

	<i>Austria.</i>	<i>Belgium.</i>	<i>Czechosl.</i>	<i>Sweden.</i>	<i>Syria.</i>
Engine . . . . .	20	15	14	10	12
Body and mechanical part . .	35	20 to 30	14	10 to 20	—
Electrical equipment . . . .	25	—	—	—	—

However, although there is this uncertainty about the average life of railcars, and consequently the fixed annual charges, it should be noted that several Administrations have directed their efforts to programmes of future construction of remarkable agreement. For example :

S. N. C. F. : 200 railcars of standard types;  
Italian State Railways : 100 railcars of 500 HP;

Swedish State Railways : 150 railcars, etc.

At the same time the standardisation of types and of the most important and common parts is being energetically pursued by all the Administrations, who have large numbers of railcars.

## SUMMARIES.

### A. Train locomotives.

1) Diesel train locomotives have already, from the technical point of view, been sufficiently perfected for use in the normal railway services with a degree of safety and regularity comparable in practice to that given by the steam locomotive.

2) The most important factor to be considered however is the economic side, which is greatly influenced by the high purchase price and higher amortisation charges, which can, however, be partially com-

control in the leading railcar (Italy);

*b) brake operated by the driver of the leading railcar, and other men on the other railcars to look after the engines and change of speed (France-Italy).*

The replies received regarding the average life of railcars do not make it possible to formulate any well founded statements. The following table leaves us still undecided :

	<i>Austria.</i>	<i>Belgium.</i>	<i>Czechosl.</i>	<i>Sweden.</i>	<i>Syria.</i>
Engine . . . . .	20	15	14	10	12
Body and mechanical part . .	35	20 to 30	14	10 to 20	—
Electrical equipment . . . .	25	—	—	—	—

pensated by a very high utilisation coefficient, but above all by the price of fuel which varies considerably from one country to another.

This latter reason and the special characteristics of the service to be operated and the countries, in which they are run, are today the fundamental factors which can lead to a widely different development of Diesel traction, both as regards its importance, and the constructional types.

3) In the United States of America the construction of steam locomotives has practically been given up in recent years in favour of Diesels. In some African and Colonial countries, the local conditions are particularly favourable to the development of this method of traction; in other countries, especially in Europe, the question has not developed any definite tendencies to date.

4) Diesel locomotives can be used as multiple units, driven by one man.

### B. Shunting locomotives.

1) In European countries, Diesel shunting engines can be divided into three categories as regards power, according to the work for which they are designed :

*a) 50 to 100 HP for shunting vehicles*

and engines in the sheds, shops and small stations;

b) 150 to 300 HP for shunting in the average sized stations;

c) 400 to 700 HP for heavy shunting operations and for use in the large marshalling yards.

2) In Europe, Diesel shunting engines are fairly widespread, and locotracors are used to a considerable extent already, whilst in the United States only locomotives are used.

3) For the types of the 3rd category Diesel locomotives with electric drive are generally used, though this does not exclude the hydraulic drive; in the case of the other two categories mechanical drive seems to be most widely used in view of the particularly favourable cost price, whereas the electric and hydraulic drives are more flexible in service.

4) Diesel shunting engines work very satisfactorily, and can be driven by one man and used as multiple units.

5) The coefficients of availability and utilisation of Diesel shunting engines are higher than those for steam traction, whilst the operating costs are definitely lower.

6) The use of locotracors is particularly indicated from the point of view of economy, to replace steam locomotives for light or intermittent shunting operations, or, on secondary lines, to haul stopping goods trains and carry out all the necessary shunting operations involved.

### C. Railcars.

1) In European countries, railcars are used almost exclusively for passenger services on secondary lines, and even as fast long distance trains on the main lines.

In the United States, railcars seem to be used to a very limited extent on secon-

dary lines, and their development does not appear to be likely.

In Europe, it should be noted that it is during recent years that the use of railcars has increased to such a rapid extent, and it appears likely that this development will continue owing to the favour it finds with the public and the operating advantages obtained, especially the flexibility and increase in the average speeds — above all on lines with heavy gradients or many stops.

In non-European countries, the use of railcars is often justified by reasons similar to those already mentioned in connection with Diesel train locomotives.

2) According to the type of service, two categories of railcars can be distinguished, i.e. the light type for economic services at moderate speeds, with a high degree of user, and the other for important services at higher speeds, with a greater specific power (10 and even 13 HP per tonne) and offering greater comfort.

3) Mechanical and hydraulic drives are the most usual in recent types; the engines are generally carried on the bogies and sometimes on the body.

4) The use of trailers, as well as coupling up in multiple units, is the general practice with the most recent types. Generally single control by one man is realised, and it is possible to pass from one unit to the other; the use of articulated rakes does not seem likely to develop on the same scale.

5) The use of adhesion railcars has proved satisfactory even on lines with very heavy gradients (75 ‰).

6) The average life of railcars seems to be 15 years for the engines and 25 years for the body.

7) In the case of future constructions, the tendency is to keep to a clearly defined classification of standardised designs.

## QUESTION XV.

**Signalling on single track lines,**

by W. A. VRIELYNCK,  
Special Reporter.

Two reports dealt with this question :

Report by H. W. JACKSON, M.Sc. Eng. (1) (Great Britain and North Ireland, Dominions, Protectorates and Colonies, America (North and South), China, Burma, Egypt, India, Pakistan, Malay States, Iraq and Iran);

Report by W. A. VRIELYNCK and P. THOMAS (2), (Austria, Belgium and Colony, Bulgaria, Czechoslovakia, Denmark, Finland, France and Overseas Territories, Greece, Hungary, Italy, Luxembourg, Netherlands and Colonies, Norway, Poland, Portugal, Rumania, Spain, Sweden, Switzerland, Syria, Turkey and Yugoslavia).

These reports are accompanied by tables showing the size and importance, features, general circumstances and operating characteristics of the various Railway systems, with details of the single line signalling arrangements which they have in service and their opinions thereon and on the matter generally.

Although a considerable number of particulars have been sent in to us on this question by those concerned, it appears to be somewhat difficult to deduce therefrom the principles under which these installations have been designed and carried into execution.

It is of course understandable that the running of trains on single line sections should be regulated in noticeably different ways, according to the characteristics of the Railway systems concerned, the districts they serve and the amount and frequency

of the traffic with which they have to deal.

In the case of a number of lines this is done without having recourse to any kind of signalling whatever. The trains are merely required to observe the prescribed timetable, which lays down that they should cross each other at certain definite places, in accordance with pre-determined operating instructions.

This method of working is entirely justified when trains run in a regular order and are few in number. Needless to say such a condition of working does not enter into consideration for our present purposes.

The various systems of signalling in use can each be considered from the following points of view :

- I. The degree of safety ensured;
- II. The speed of operation;
- III. The staff required to work them; and
- IV. Their costs of installation, maintenance and operation.

Let us consider briefly these various aspects of the question.

#### **I. The degree of safety ensured.**

Safety is only fully ensured by using one of the following systems :

- ordinary train-staff, and a shuttle train service;
- « token » system;
- electric train-staff system;
- automatic block working.

In the case of automatic signalling, light signals lighted and extinguished by the

(1) See *Bulletin of the International Railway Congress* for May 1950, p. 1047/1.

(2) See *Bulletin of the International Railway Congress* for July 1950, p. 1487/23.

passage of the train itself, authorise or prohibit as circumstances require, entry to the single line section. It is evidently essential that any defect, any failure to function, any interruption to the current, must be equivalent to the latter condition, i.e. it must keep the single line section blocked.

It is also desirable that the main signal lights should be repeated at intervals along the single line section concerned, by means of additional repeating lights.

The other systems are open to the risk of mistakes being made (as in the case of, say, telephone messages) during the course of the transmission of information, or in writing down what has been transmitted.

There is moreover no kind of interlocking control between the giving of permission to enter the single line section at one end, or the prohibition of doing so at the other.

## II. Speed of operation.

Automatic signalling reduces to a minimum the time lost when trains are crossing. If the line is clear the train does not stop but merely reduces speed somewhat.

Signalling by means of telephone messages and semaphore or light signals is capable of giving in this respect the same speed of operation.

## III. Staff required.

Among those systems requiring action to be taken only by the *train crews* (in this respect the most economical), the most elementary make use of the ordinary plain train-staff. The most developed and complete of these types of signalling require the use of electric apparatus, relays and light signals, lighted up and extinguished by the passage of the train itself (automatic block).

The remaining systems require *special staff stationed at defined points* along the line whose duty it is to regulate the run-

ning of the traffic, and when the conditions require it, actuate the signals. Among these systems we find the « token » system, and the various methods of telephone working (under a traffic controller, using the space interval, or some actual block apparatus, etc.) in conjunction with mechanical or electrical type signals.

## IV. Cost of installation, maintenance and operation.

Signalling by means of the ordinary train staff is evidently the most economical in every respect.

Then come after that, as regards cost of upkeep, the « token » system, telephone working and the electric train-staff.

Automatic block working, in whatever form it may take, would seem at first sight of necessity very expensive, both in first cost and upkeep.

We give on the following page the costs, as reported to us by those concerned, of installation and maintenance of the single line signalling equipment on the Railways shown.

The particulars given do not allow of determining, short of special information on the matter, to what systems of signalling these costs refer. It is very clear that the systems are not comparable with one another in any way.

We assume that certain Railways have included equipment at the stations which is in fact not a part of the single line signalling, properly so-called.

We have not had sufficient time to enable us to get in touch with those concerned in order to clear up this point. It is very likely too that the more expensive systems include advantages and improvements, deserving of being specially referred to.

What strikes the attention most is the fact that the system adopted by the Belgian National Light Railways (S. N. C. V.) seems specially cheap, although it is an automatic block system. The reason for that probably is that the installation is a signalling one, pure and simple. As each

	Fist cost in dollars per km	Maintenance cost in dollars per year
Victorian Railways :		
City and suburban . . . . .	25 000	1 000
Outer suburban . . . . .	31 000	1 200
Main trunk lines . . . . .	25 000	500
Secondary branch lines . . . . .	1 700	30
Norway . . . . .	15 000	200
Luxemburg . . . . .	14 000	120
Switzerland . . . . .	12 000 or 4 000	
South Africa . . . . .	11 000	700
Netherlands . . . . .	10 000	50
Great Britain . . . . .	8 500	170
Greece . . . . .	5 000	200
Egypt . . . . .	1 100	140
U. S. A. :		
Automatic block . . . . .	3 600	200
Centralised traffic control . . . . .	7 000	420
Belgium (S. N. C. V.) (Light Railways Co.) :		
Automatic block . . . . .	1 000	50

of the two tracks at the crossing stations is kept for one direction of running there is no need to have any means of actuating or detecting the points.

#### SUMMARIES.

1. Lines of small importance carrying a light regular traffic can very well dispense with any special single line signalling, the crossing of trains taking place at definite points laid down in advance and which must be adhered to.

2. Lines lending themselves to be worked with a shuttle service use the ordinary plain train-staff.

3. The lines carrying a more important and relatively irregular traffic, passing through districts where the cost of labour is low and technically competent persons rarely met with (as in the Colonies) have usefully had recourse to the Webb & Thompson electric train-staff, which affords all the safety that can be desired. It is moreover of simple design and robust construction.

4. Lines where there is considerable traffic and overall speed is high tend to adopt automatic signalling. When a line is laid on its own inaccessible right of way, track circuits are used. If it is laid alongside or in the roadway itself, i.e. if it has the character of a tramway line, it becomes necessary to use special circuits and overhead contact makers, or « trolley contactors ». It is in any case useful to arrange for repeating lights, as this increases the safety of operation.

It appears that amongst the Railway systems whose opinion has been asked, there are very few that are of this kind. This explains why the Belgian National Light Railways Company is apparently the only one using this system of signalling.

5. All lines are agreed in not permitting, under normal conditions, more than one train at a time to be in a single line section and in prohibiting setting back in the section.

6. On those lines where the traffic is

regulated by telephone, the signals used appear to be those controlling the stations themselves rather than the actual single line. In consequence they are outside the scope of the matter under discussion in this statement.

7. Telephone working under the control of staff located at fixed points along the line (traffic controllers or regulators, stationmasters) allows of dealing easily and quickly with any unexpected situation that may arise. It is conceivable that it will continue to be used where it is necessary to employ stationmasters on account of there being a considerable goods traffic to be dealt with.

*Note.* — No Railway to our knowledge is making use of radio-telephony. This implies control over the train running by a traffic controller or dispatcher constantly in communication with the guards of the various trains, to whom he would have to give instructions and of which they would be able to acknowledge receipt. This system would cost but little to install and to maintain, and it would be able to be worked quickly and allow of dealing easily with any unexpected conditions. From the safety point of view, however, it would evidently offer all the disadvantages of systems liable to give rise to mistakes when transmitting messages, a defect inherent in all telephonic communications.

## ERRATUM

### Bulletin for May 1950.

Report by J. R. FARQUHARSON.

### Question XIII. — (15th Session, Rome 1950).

Page 1070/56 :

Table I, column « RAILWAY » :

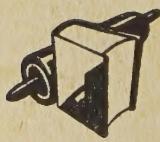
The words : *Railway Board India* must be replaced by : *Bengal Nagpur Railway, India.*

Page 1071/57 :

Table II, column « RAILWAY » :

The word : *India* must be replaced by : *Bengal Nagpur Railway, India.*





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